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SELECTED PHYSICAL PROPERTIES OF AFRICAN PEAR SEED FORCONSIDERING IN DESIGN OF MECHANICAL EXPELLER

Busari R. A.[1] and Olaoye J. O.[2]
[1]Food, Agricultural and Bio-Engineering Department, Kwara State University Malete, Nigeria
[2]Agricultural and Bio Systems Engineering, Faculty of Engineering, University of Ilorin, Nigeria
E-Mail: rasheed.busari@kwasu.edu.ng

ABSTRACT

The study was conducted to investigate the physical properties of African pear seeds, the flesh African pear seed was purchased from Ojo market in Ibadan and mesocarps of the fruits were removed to obtain the nuts. The nuts were dried under ambient conditions for several days, the actual moisture content of the nuts at the time of experimentation was determined, using KT100S Moisture Meter with measuring range of 5-35% to be 21.50%. The nuts were sorted into three grades: small, medium and large, based on the visual physical assessment of their sizes. The three principal axial dimensions of 250 nuts from each grade were measured using a vernier caliper. In this study some selected physical properties of African pear seeds were determined which are essential for designing engineering processes, material handling, storage, equipment design and fabrication. The physical properties, namely, arithmetic mean diameter, geometric mean diameter, surface area, sphericity, aspect ratio, true density and bulk density were determined. Also, angle of repose and coefficient of friction were tested on mild steel, plywood and PVC plastic which are probable engineering materials for construction of food processing equipment. The results revealed that average geometric mean diameters of the nuts are 25.22, 30.74 and 35.26 mm for the small, medium and large size grades respectively. The nuts are fairly ellipse with average sphericity of 0.54, 0.54 and 0.59 for the small, medium and large size grades respectively while true and bulk density0.96 g/cm^3 and 1.14 g/cm^3 respectively. The angles of repose were 40.99, 47.92 and 47.53 small, medium and large size respectively. These findings can provide the information that could be helpful for development of mechanical expeller or processing machines.

Keywords: african pear seed, fruit, nut, physical properties.

INTRODUCTION

Dacryodesedulis is a shade-loving species of non-flooded forests in the humid tropical zone. Where there is a well-marked season, it is found only in gallery forest and on swampy ground. The tree can be cultivated widely, since it adapts well to differences in day length, temperature, rainfall, soils and altitude. It is planted in southern Nigeria, Cameroon and Democratic Republic of Congo for its nutritious fruit, which has high oil content. It belongs to the family of Burseraceae, which is known as *Safou*in French, *ube*in Ibo, *elemi* (Yoruba), *eben* (Efik) and *orumu* (Kengue *et al*., 2002; Nwokeji *et al*., 2005). In south-east Nigeria, the trees are grown around homesteads.

The plant flowers between February and March. The flowers cluster at the end of the branches. It fruits between May to August, and the fruit is about 4 to 9cm long and 2 to 5cm in diameter, hanging in clusters, at first pinkish, and then blacken when ripe. It is usually eaten either raw as desert, boiled in water, roasted in hot ash or grilled in oven. The mesocarp softens to form a kind of butter, which is eaten in conjunction with boiled or roasted corn. The African pear fruits help to ameliorate the food scarcity during the planting season. The fruit mesocarp contains 43.99% fat and 4.47% protein (Ajiwe*et al.,* 1997). The seed is often discarded and constitutes a big waste in towns and villages (Ajiwe*et al.,* 1997).The use of vegetable oils as a substitute for diesel fuel in engines is receiving increased attention. This potential energy source is renewable; it could reduce the risk of unavailability of fossil fuel (diesel), and could to a large extent reduce pollution effects resulting from the waste seed. It is on this basis that the African pear seed will be analyzed for the physical and engineering properties of its oil that will enable it to be used as a substitute for diesel oil as well as looking at the possibility of the use of the defatted seed as feed for animals (Ajiwe*et al.,* 1997).Plate 1 and 2 shown tropical African pear fruits and dried nut. The oil from African pear seeds can be extracted using various methods.

Oil extraction is the process of recovering oil from oil-bearing agricultural products through manual, mechanical, or chemical extraction. Plants bearing these agricultural products (oils) have greatly contributed to the economic development of many countries especially the development of West African countries where the products are grown for commercial purposes (Ibrahim and Onwualu, 2005). The Oil Expeller is a screw type machine, which presses oil seeds through a caged barrel-like cavity. Raw materials enter one side of the press and subjected to increasing pressure while the waste products exit the other side. The machine uses friction and continuous pressure from the screw drives to move and compress the seed material. The oil seeps through small openings that do not allow seed fiber solids to pass through. Afterward, the pressed seeds are formed into a hardened cake, which is removed from the machine. Expeller pressing is a mechanical method for extracting oil from raw materials. Expellers can be used with almost any kind of oilseeds and nuts. The process is not capital-intensive, relatively simple and available for much smaller capacities.The main disadvantage of the screw-press process is its relatively low yield of oil recovery.

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The physical properties of African pear are important in the design of equipment for harvesting, cleaning, sorting, grading, packaging and processing. These properties can also affect the handling/conveying characteristics and estimating the cooling and heating loads (Ali, 2012). Since the current used systems have been generally designed without taking these criteria into consideration; the resulting design leads to inadequate applications. This results in a reduction in work efficiency and an increase in product loss. Therefore, determination and consideration of these criteria have an important role in designing the equipment. With respect to economical and processing importance of African pear seed, overcoming the world market and decreasing product losses, investigation and development in the field of selection or designing of the most suitable machine for it is necessary.

The aim of this research was to investigate the physical properties of African pear in order to achieve a complete profile of these attributes. The physical characteristics studied were major, minor and intermediate axle, true density, bulk density, geometric and arithmetic mean diameters, aspect ratio, Sphericity, Surface Area, Coefficients of Static Friction (galvanized steel, plywood and glass) and angle of repose.

Plate-1. African pear fruits.

Plate-2. Dried African pear kernels with nuts.

MATERIAL AND METHODS

Two bags of fresh African pear fruits were purchase from a large stock obtained from Oje fruit market, Ojo and Moniya all in Ibadan, Nigeria. The fleshy mesocarps of the fruits were removed to obtain the nuts. The nuts were dried under ambient conditions for several days, following the prevailing cultural practices by the local farmers and processors of nuts.

Sample preparation

The actual moisture content of the nuts at the time of experimentation was determined, using KT100S Moisture Meter with measuring range of 5-35% to be 21.50%. The nuts were sorted into three grades: small, medium and large, based on the visual physical assessment of their sizes. The three principal axial dimensions of 250 nuts from each grade were measured using a vernier caliper. Measurement along the longitudinal axis, from the point of attachment to the base, was taken as the major diameter. The two mutually perpendicular dimensions in the transverse axes were taken as the intermediate and minor diameters.

Determination of the physical properties

Arithmetic mean diameter

The arithmetic mean diameter of the kernel was determined from the three principle diameter using the relationship by (Mohsenin, 1970):

$$D_a = \frac{(a+b+c)}{3} \tag{1}$$

Where,

D_a = Arithmetic mean diameter (mm)
a = major diameter, (mm)
b = intermediate diameter, (mm)
c = minor diameter, (mm)

Geometric mean diameter

The geometric mean diameter was determined from the major (a), intermediate (b) and minor (c) diameter using the formula; Geometric mean diameter,

$$D_g = (a.b.c)^{1/3} \tag{2}$$

Where,

D_g = Geometric mean diameter (mm)
a = major diameter,(mm)
b = intermediatediameter,(mm)
c = minordiameter, (mm)

Sphericity determination

The sphericity of the kernel was calculated by using the following relationship (Mohsenin, 1970):

Sphericity, $(\phi) = \frac{D_g}{a} \times 100$ (3)

Where,

D_g = Geometric mean diameter (mm)

a = major diameter

Surface area

The surface area was determined by using the following equation as cited by (Tunde-Akintunde and Akintunde, 2004; Altuntas *et al.,* 2005):

$$S = \pi (D_g)^2 \quad (4)$$

Where;

S = surface area (mm^2)

D_g = geometric mean diameter

Aspect ratio

The aspect ratio was also computed from the values obtained for major axis (length) and minor axis (width). It is given as follows in equation 5:

$$R_a = \frac{b}{a} \times 100 \quad (5)$$

Coefficient of friction

Coefficient of static friction is the tangent of the angle of inclination at which a material begins to slide on the surface. Using the method described by Owolarafe and Shotonde (2004). The Coefficients of static friction of seeds on the three different surfaces including plywood, galvanized iron sheet, and glass were determined. The seeds were placed on the surface of an inclined apparatus. The plane portion of the apparatus was raised. The angle of inclination to the horizontal, as soon as the fruits began to slide, was measured from a protractor attached to the inclined plane. The coefficient of friction was calculated from the following equation

$$\mu = \tan \alpha \quad (6)$$

Where

μ = the coefficient of friction and

α = the angle of tiltin degree.

True density

The true density (ρ_t) of the fruit was determined by water displacement method. Fifty randomly selected African pear seeds were weighed and lowered into a graduated measuring cylinder containing 100 ml of water. It was ensured that the fruit was submerged during immersion in water. The increase in volume was noted. The ratio of the mass (g) of the fruit to the volume (cm^3) of water displaced due to the immersed fruit gave the density of the fruit (Altuntas *et al.,* 2005).The true density was calculated as:

$$True\ Density = \frac{weight\ of\ the\ sample}{volume\ of\ distilled\ water\ displaced} \quad (7)$$

Bulk density

A cylindrical container of known mass and volume was filled with African pear seedsand weighed. Themass of the African pear seedswas calculated by the difference between the weight of the empty cylinder and the massafter it was filled with the African pear seeds. The ratio of the mass of the African pear seedsto the volume of the cylindrical container gives the bulk density (ρ_b) (Amin *et al.,* 2004).The bulk density was calculated as:

$$Bulk\ Density = \frac{weight\ of\ sample}{volume\ occupied} \quad (8)$$

Determination of angle of repose

A regular cylindrical container opened at both ends and placed on a galvanizedsteel surface was filled with the African pearseeds to the brim. Afterwards the container was lifted gradually and finally emptied to form a conical heap with the seeds. The tangent of the angle of inclination to the horizontal ($\tan\theta$) was calculated from the height (h) and base radius (r)of the formed heap a (Amin *et al.,* 2004);

$$Tan\ \theta = \frac{h}{r} \quad (9a)$$

$$\theta = \tan^{-1}\left(\frac{h}{r}\right) \quad (9b)$$

Where,

θ = the angle of repose

h = height of the pile (mm) and

d= radius of the pile (mm).

RESULTS AND DISCUSSIONS

The determined physical characteristics of African pear seeds are presented in Table-1.

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Table-1. Some physical properties of African pear.

Physical Property	Minimum value	Maximum value	Mean	Standard Deviation	Coefficient of Variation	No of sample
Small Sample						
Major axle (mm)	33.00	51.50	42.25	4.45	19.77	250
Minor axle (mm)	14.00	23.50	18.09	1.86	3.46	250
Intermediate axle (mm)	12.00	21.00	15.33	1.62	2.63	250
Medium Sample						
Major axle (mm)	41.00	59.50	49.19	3.33	11.09	250
Minor axle (mm)	17.00	32.00	22.97	2.40	5.78	250
Intermediate axle (mm)	15.00	29.00	20.07	2.28	5.20	250
Large Sample						
Major axle (mm)	48.00	68.50	55.31	3.71	13.73	250
Minor axle (mm)	19.50	37.00	26.60	2.74	7.53	250
Intermediate axle (mm)	18.00	31.50	23.86	2.49	6.19	250
Arithmetic Mean Diameter (mm)						
Small	21.67	30.00	25.22	1.70	2.88	250
Medium	26.67	37.67	30.74	2.08	4.32	250
Large	29.17	41.50	35.26	2.23	4.95	250
Geometric Mean Diameter (mm)						
Small	19.63	27.54	22.64	1.56	2.44	250
Medium	23.22	35.77	28.26	2.18	4.75	250
Large	25.99	39.21	32.68	2.31	5.35	250
Surface Area (mm^2)						
Small	1210.28	2382.41	1617.94	228.36	52148.53	250
Medium	1693.77	4019.73	2523.46	397.85	158285.49	250
Large	2121.90	4831.05	3373.26	480.25	230641.23	250
Sphericity (%)						
Small	44.16	69.97	54.07	5.70	32.44	250
Medium	48.06	68.73	54.07	3.85	14.83	250
Large	48.15	69.52	59.20	3.83	14.64	250
Aspect Ratio (%)						
Small	31.25	64.71	43.39	6.99	48.87	250
Medium	34.26	58.89	46.81	4.88	23.83	250
Large	35.59	66.02	48.23	5.28	27.83	250
True Density (g/cm^3)						
Small	0.77	1.28	0.96	0.10	0.01	50
Medium	0.71	1.24	0.98	0.12	0.02	50
Large	0.86	1.16	0.96	0.05	-	50
Coefficients of Static Friction (^{o}) [galvanized steel]						

Small	0.18	0.47	0.33	0.07	0.01	50
Medium	0.18	0.49	0.35	0.06	0.00	50
Large	0.18	0.49	0.35	0.07	0.01	50
Coefficients of Static Friction (°) [plywood]						
Small	0.16	0.47	0.28	0.08	0.01	50
Medium	0.19	0.53	0.35	0.08	0.01	50
Large	0.19	0.55	0.36	0.09	0.01	50
Coefficients of Static Friction (°) [glass]						
Small	0.25	0.45	0.36	0.05	0.00	50
Medium	0.23	0.46	0.35	0.04	0.00	50
Large	0.14	0.43	0.32	0.07	0.00	50
Angle of Repose (°)						
Small	39.56	42.4	40.99	1.42	2.02	3
Medium	46.22	50.6	47.92	2.35	5.53	3
Large	48.50	46.69	47.53	0.91	0.83	3
Bulk Density (g/cm^3)	1.09	1.18	1.14	0.05	0.002	3

Physical characteristics

The physical dimensions of the African pear seeds at 21.5% moisture content (wet basis) at the time of the experiment are summary in Table-1. As it can be seen, the average major, minor and intermediate axles were found to be 42.25, 18.09 and 15.33 mm, respectively for the small sample and that of medium sample were found to be 49.19, 22.97 and 20.07mm respectively while the average major, minor and intermediate axles for large sample were found to be 55.31, 26.60 and 23.86mm respectively. The importance of these dimensions in determining aperture size of machines, particularly in separation of materials has been discussed by (Ali, 2012). The major axis has been found to be indicating the natural rest position of the material and hence in the application of compressive force to induce mechanical fracture. Also, this dimension will be useful in applying shearing force during slicing (Owolarafe and Shotonde 2004).

The average geometric mean diameters of the nuts are 25.22, 30.74 and 35.26 mm for the small, medium and large size grades respectively. The nuts are fairly ellipse with average sphericity of 0.54, 0.54 and 0.59 for the small, medium and large size grades respectively. The sphericity of the small and medium sizes was almost identical while that of large sizes was a little bit higher. This is very important in design of hoppers for processing machines. Owolarafe *et al* (2006)reported that, the true and bulk density (0.96 g/cm^3 and 1.14 g/cm^3 respectively) characteristics are useful in the estimation of load and hence in the design of load shafts for processing machine. The angles of repose were 40.99, 47.92 and 47.53 small, medium and large size respectively. The static coefficients of friction of pear seeds against three different structural surfaces were measured. The results indicated that the glass and galvanized steel surface had almost the same value of static coefficient of friction and the value is higher than plywood

CONCLUSIONS

The physical characteristics of African pear seed were investigated to establish the minimum value, maximum value, mean, standard deviation and coefficient of variation of the seed.

The measurements were undertaken along three axes namely major, minor and intermediate axles while the seeds were classified into small, medium and large size.
The angle of repose ranges between 39.56° and 50.60°. The values for sphericity, true density, bulk density and, coefficients of static friction (galvanized steel, plywood and glass) range between 44.16 and 69.97 %, 0.71 and 1.28 g/cm^3, 1.09 and 1.18 g/cm^3, and 0.14 and 0.46, respectively.

These parameters were needed as a first step in design of specific equipment for the crop processing and this will facilitate the design of the machines involved in processing of the African pear seed.

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