Int. Agrophysics, 2007, 21, 123-126

INTERNATIONAL
Agrophysics
www.ipan.lublin.pl/int-agrophysics

Some physical properties of African nutmeg (*Monodora myristica*)

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Received February 21, 2007; accepted May 16, 2007

A b s t r a c t. Physical and some frictional properties of African nutmeg *(Monodora myristica),* a wild perennial edible plant, were investigated at a moisture content level of 4.93% dry basis. Measured values for sphericity, unit volume, average geometric diameter, unit mass, true density, bulk density, surface and projected areas were 0.74 ± 0.064, 1008 mm^3 ± 169, 12.42 mm ± 0.70, 0.89 g ± 0.14, 830, 488 kg m^{-3}, 483 and 1216 mm^2, respectively. The average values for coefficient of static friction on four test surfaces ranged from 0.502 (for galvanized iron sheet) to 0.702 (for rubber). Thus, the technical data obtained from this study may be useful in the design of process machines.

K e y w o r d s: African nutmeg, physical properties, design

INTRODUCTION

Effective and proper design of machines and processes for harvesting, handling and storage of agricultural materials and for converting these materials into food requires an understanding of their physical properties. These properties include the size, shape, mass, volume, sphericity, bulk density, true density, porosity, geometric mean diameter, projected area, surface area, radius of curvature, etc. The study of size of fruits and seeds is essential for uniformity and packing in standard cartons. Bulk density and porosity are useful in containerisation, transportation and separation systems (Kachru *et al*., 1994). Shape and physical dimensions, such as major, intermediate and minor diameters, unit mass, volume and sphericity, are important in screening solids to separate foreign materials and in sorting out various sizes of fruits and vegetables (Stroshine, 2005). Also the knowledge of frictional properties is needed for design of handing equipment and storage structures (Mohsenin, 1970; Peleg and Bagley, 1983). These engineering properties are not only useful to the engineers but also to food scientist and processors who may exploit them in their various disciplines.

African nutmeg *(Monodora myristica)*, belonging to the Ananacea family, is one of the most important trees of the evergreen forest of West Africa. It is most prevalent in the Southern region of Nigeria (Adegoke and Akinsanya, 1970). Almost every part of the tree has economic importance (Okafor, 1987; Okigbo, 1977). However, the most economically important parts are the seeds which are embedded in the white sweet-smelling pulp of the sub-spherical fruit (Fig. 1). After harvesting, between April to September every year (Ejiofor *et al.*, 1998), a series of unit operations (fermentation, washing, drying and cracking) are carried out. The kernel is obtained by cracking the nuts, which is easier done by heating. The kernel, when ground to power, is a popular condiment used to prepare pepper soup as a stimulant to

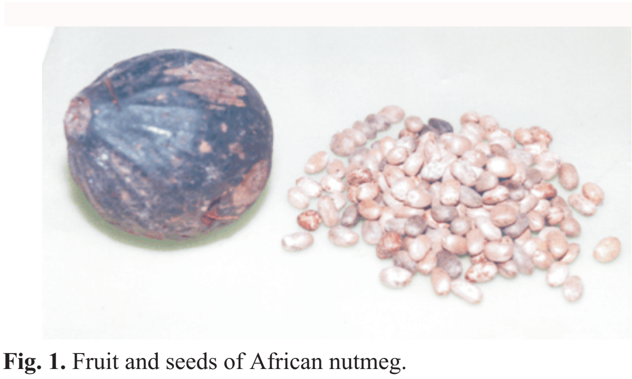

Fig. 1. Fruit and seeds of African nutmeg.

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relieve constipation and to control passive uterine hemorrhage in women immediately after child birth (Okafor, 1987; Iwu *et al*., 1987; Udeala *et al*.,1980). It also has diuretic properties and is used for mild fever (Iwu *et al*., 1987).

However, the most demanding aspect of all the unit operations is the cracking of the nut to extract the kernel, which is still carried out by cracking between stones. This operation is yet to be mechanized to reduce the drudgery associated with it as well as to open up an avenue for large scale production.

But there is paucity of information on the physical properties of African nutmeg. These properties therefore need to be investigated and utilized in the design of various post-harvest systems.Therefore, the objectives of this study were to investigate the physical properties such as length, diameter of seeds, volume, unit mass, geometric mean diameter, sphericity, bulk density, true density, projected area, surface area, porosity, radius of curvature and coefficient of static friction.

MATERIALS AND METHODS

Fresh African nutmeg fruits were collected from the Sabageria forest, Nigeria, on the 30th July, 2006. The fruits were processed and all foreign matter and damaged seeds were removed. The seeds were then stored at 0°C and 90% relative humidity for 48 h. The moisture content was measured on arrival. The temperature and relative humidity during testing were 30°C and 68%, respectively.

All physical properties were determined at moisture content of 4.93% d.b.

For 100 seeds, a) major, b) intermediate, and c) minor diameters were measured using a digital vernier caliper (Model CD 15CP-Mitutoyo, England), having a resolution of 0.01 mm. The geometric mean diameter (GMD) was calculated as:

$$GMD = (abc)^{1/3}. \quad (1)$$

Sphericity (*f*) was calculated adopting the formula proposed by Mohsenin (1970) as:

$$f = \frac{(abc)^{1/3}}{a}. \quad (2)$$

The unit volume of 100 individual seeds was calculated from values of *a*, *b*, and *c*, invoking the equation proposed by Miller (1987):

$$V = \frac{\pi abc}{6}. \quad (3)$$

The unit mass of 100 individual seeds was measured using a top-loading electronic balance (Model 6330, OIPPL, India), having an accuracy of ± 0.01 g. The average value, standard deviation, minimum and maximum values were calculated. Using a SAS software package (2004), the relationship between mass and volume for African nutmeg was established.

The projected area of 100 individual seeds was determined using the unit volume as obtained above and calculated with the formula by Li *et al*. (1998):

$$Ap = \mathrm{K} V^{2/3}, \quad (4)$$

where: A_P – average projected area (mm^2), K – constant = 1.21 and V – project volume (mm^3).

Similarly, the surface area of the seeds was calculated using the formula (Li *et al*., 1998):

$$A_s = (36\pi)^{1/3} V^{2/3}, \quad (5)$$

where: A_s – average surface area (mm^2), V – project volume (mm^3).

Bulk density of African nutmeg seeds was determined using a cylindrical container (volume = 250 x 10^{-6} m^3). The container was filled with seeds, and seeds having half of their length projected above the top edge were removed and the entire content weighted in a top-loading electronic balance. The bulk density was calculated as (Li *et al.*, 1998):

$$\ell_d = \frac{W_b}{V_b}, \quad (6)$$

where: ℓ_d – bulk density (kg m^{-3}), W_b – mass of seeds (kg), V_b – volume of container (m^3).

The true density was measured using the values of unit volume and unit mass of individual seeds and calculated using the formula proposed by Li *et al*. (1998) as:

$$\ell_{Tr} = \frac{m}{V}, \quad (7)$$

where: ℓ_{Tr} – true density (kg m^{-3}), m – mass of individual seed (kg), V – volume (m^3).

Porosity, *P*, was calculated from average values of bulk density and true density. An average of 5 replications were taken as representative values of both bulk and true densities. Porosity was then calculated as (Thompson and Isaac, 1967):

$$P = \frac{\ell_{Tr} - \ell_b}{\ell_{Tr}} 100. \quad (8)$$

The radii of curvature for 100 seeds were individually determined using ASAE S368.4 (2000), and the average value and standard deviations were taken. The values were calculated assuming convex shape for samples, as:

$$R_1 = b/2, \quad (9)$$

$$R_2^1 = \frac{b^2 + a^2/4}{2b}, \quad (10)$$

where: R_1, R_2 – minimum and maximum radius (mm), *a, b* – major and intermediate diameters (mm).

The coefficient of static friction was evaluated using iron sheet, galvanized iron sheet, plywood, and rubber. As suggested by Musa and Hayder (2004) and Suthar and Das (1996), one end of the friction surface (inclined plane) was attached to an endless screw. Seeds were placed on the surface and it was gradually raised by the screw. Both horizontal and vertical height values were measured by a rule when the seeds started sliding over the surface and, using the tangent of that angle, the coefficient of static frication was calculated as:

$$\mu_s = \tan \alpha$$

where: μ_s – coefficient of static friction, $\propto$ – angle that the incline makes with the horizontal when sliding begins.

Statistical evaluation was done using SAS Software (2004).

RESULTS AND DISCUSSION

A summary of the descriptive statistics of the various physical dimensions is shown in Table 1. The average major, intermediate, and minor diameters for African nutmeg were 16.67, 11.52 and 9.98 mm, respectively. These valves of physical dimensions of African nutmeg are quite different from those reported by Musa and Haydar (2004) for Sumac fruits, which are 4.72, 3.9 and 2.64. The GDM, with an average value of 12.43 (± 0.7), varied between 10.67 and 14.21 mm.

Average sphericity was obtained as 0.74 (±0.0.064). This value is close to the values reported by Musa and Haydar (2004) for Sumac fruits (0.77 ± 0.003). The fairly high sphericity values for African nutmeg shows features favourable to rolling of the fruits and therefore have a practical application in handling operations such as conveying and grading.

As shown in Table 1 above, the volume of African nutmeg varied from 635.2 g mm^{-3} (seed mass: 0.83 g) to 1489.47 mm^3 (seed mass: 1.07 g), with an average value of 1008.59 mm^3. This value is quite different from what Musa and Haydar (2004) reported on Sumac fruits.

However, comparing seed major diameter, intermediate diameter, minor diameter and volume, a relationship is established using multiple linear regression analysis (r^2 = 0.89).

The average values for the minimum and maximum radius of curvature of the seeds were 5.76 (± 0.458) and 9.42 mm (± 0.653), respectively. Similarly, the average surface area was found to be 1216.72 mm^2 (± 202.69). Average projected area varied from 357.18 to 630.33 mm^2, with a mean value of 483.71 mm^2 (± 53.71).

However, regression analysis shows a correlation between radii of curvature, average surface area, projected area and volume. This is valid within the experimental limits:

A_p = - 2099.3 + 298.1 R_1 + 169.8 R_2 (r^2 = 0.79),

A_s= - 392.6 + 78.3 R_1+ 45.2 R_2 (r^2 = 0.74),

V=1780.2 + 249.2 R_1 + 143.7 R_2 (r^2 = 0.74).

As shown in Table 2 above, the true density of African nutmeg was found to be 830.54 (±17.50) kg m^{-3} while the bulk density was obtained as 488.76 (± 10.10 kg m^{-3}), yielding a porosity of 41.10% (±1.20). This porosity value is similar to that reported by Thomson and Isaac (1967) for soy beans (41-44%).

A summary of frictional properties data of African nutmeg on different surfaces is also presented in Table 2. Values obtained reveal that the coefficient of static friction, using iron sheet, galvanized iron, plywood and rubber surfaces, were 0.554 (±0.022), 0.502 (±0.013), 0.632

T a b l e 1. Physical properties of African nutmeg (number of seeds = 100)

Properties	Minimum	Maximum	Mean	Standard deviation
Major diameter (mm)	5.00	21.18	16.6762	1.9105
Intermediate diameter (mm)	9.06	14.10	11.5193	0.9155
Minor diameter (mm)	8.00	12.20	9.9805	0.9370
GDM (mm)	10.67	14.21	12.4271	0.7005
Sphericity (-)	0.61	0.89	0.7429	0.0643
Volume (mm^3)	635.29	1489.47	1008.3993	169.5765
Mass (g)	0.52	1.26	0.8975	0.1482
Minimum radius (mm)	4.53	7.05	5.7601	0.4576
Maximum radius (mm)	7.30	11.45	9.4157	0.6526
Projected area (mm^2)	768.70	1902.26	1216.7157	202.6890
Surface area (mm^2)	357.18	630.00	483.7089	53.4111

T a b l e 2. Some physical properties of African nutmeg at 4.93% d.b.

Properties	Values
True density (kg m^{-3})	830.54 ± 17.50
Bulk density (kg m^{-3})	488.76 ± 10.10
Porosity (%)	41.10 ± 1.20
Coefficient of static friction	
Iron sheet	0.554 ± 0.022
Galvanized iron sheet	0.502 ± 0.013
Plywood	0.632 ± 0.037
Rubber	0.702 + 0.146

(±0.037) and 0.702 (±0.0164), respectively. This trend indicates that rubber has the highest coefficient of static friction and galvanized iron sheet the least. It was observed from the experimental values that surface materials have a significant effect on the coefficient of static friction. Comparatively, the African nutmeg seed coefficient of static friction has semblance with that of Sumac fruits (Musa and Haydar, 2004), Rose fruit (Demir and Ozcan, 2001) and Juniperus drupacea (Akinci *et al*., 2004). Thus, information on the physical properties of African nutmeg is essential for the initial design of equipment for handing, transport, processing and storage of seeds.

CONCLUSIONS

1. Some physical properties of African nutmeg were determined at a moisture content level of 4.93% dry basis.

2. The seed volume, major, intermediate, and minor diameters, sphericity, mass, project were obtained as 1008.599 mm^3, 16.67, 11.51, 9.98 mm, 0.74, 0.89 g and 1216.72 mm^2, respectively.

3. At the same moisture level, bulk density, porosity and true density were also evaluated as 488.78 kg m^{-3}, 41.1%, 830.54 kg m^{-3}, respectively.

3. The evaluation of coefficient of static friction on different surfaces reveals galvanized iron sheet to have the least value, with rubber having the highest coefficient. These findings may be relevant for food engineers and African nutmeg processors.

4. The provision of physical properties data of African nutmeg, such as mean diameter and unit mass, could be used to design sorters and grading machines. On the other hand, bulk and true density information provided here is essential for design of aerodynamic equipment for separation processes.

REFERENCES

Adegoke E. and Akinsanya A., 1970. Studies of Nigeria medical plants. J. West African Sci. Assoc., 13(2), 13-33.

Akinci I.A, Ozdemir F.B, Topuz A.B., Kabas O.A., and Canakci M.A., 2004. Some physical and nutritional properties of *Juniperus drupacea* fruits. J. Food Eng., 65/3, 325-331.

ASAE Standard, 10th Ed., **2000**. S368.4. Compression Test of Food Materials of Convex Shapes. ASAE Press, St. Joseph, MI.

Demir F. and Ozcan M., 2001. Chemical and technological properties of rose (*Rosa canina* L.) fruits grown wild in Turkey. J. Food Eng., 47(4), 333-336.

Ejiofor M.A.N., Onwubuke S.N., and Okafor J.C., 1998. Developing improved methods of processing and utilization of kernels of *Irvingia gabonensis* (var. gabonensis and var. excelsa). Int. Tree Crops J., 4(3), 283-290.

Iwu M.M., Igboko A.O., Okunji C.O., and Onwuchekwa U., 1987. Evaluation of the anthihepatotoxic activity of the biflavonoids of *Garciaria kola* seeds. J. Enth. Pharmacol., 21(2), 127-138.

Kachru R.P., Gupta R.K., and Alam A., 1994. Physico-Chemical Constituents and Engineering Properties of Food Crops. Scientific Publishers, Jodhpur, India.

Li M., Davis D.C., Obaldo G.L., and Barbosa-Canovas G.B., 1998. Engineering Properties of Foods and other Biological Materials (A Laboratory Manual). ASAE Press, St. Joseph, MI.

Miller W.M., 1987. Physical properties data for post-harvest handling of Florida citrus. Appl. Eng. Agric., 3(1), 123-128.

Mohsenin N.N., 1970. Physical Properties of Plant and Animal Materials. Gordon and Breach Sci. Publishers, New York.

Musa O. and Haydar H., 2004. A condiment (*Sumac Rhus Coriaria* L.) fruits): some physico-chemical properties. Bulg. J. Plant Physiology, 30(3), 74-84.

Okafor J.C., 1987. Development of forest tree crops for food supplies in Nigeria. Forest Ecol. Man., 1, 235-247.

Okigbo B.N., 1977. Neglected plants of horticultural importance in traditional farming systems of tropical African. Acta Hort., 53, 131-150.

Peleg M. and Bagley B., 1983. Physical Properties of Foods. AVI Publishing Company, Westport, CT.

SAS, **2004.** Statistical Analysis Software Programs Package (SAS Institute, Version 9.0).

Stroshine R., 2005. Physical Properties of Agricultural Materials and Food Products (Teaching material). Dept. Agric. Eng., Purdue Univ., West Lafayette, IN.

Suther S.H. and Das S.K., 1996. Some physical properties of karvingda (*Citrullus lanatus* Mansf) seeds. J. Agric. Eng. Res., 65(1), 15-22.

Thompson R. and Isaac W., 1967. Porosity determination of grains and seeds with air comparison pycnometer. Transactions of the ASAE, 10(5), 693-696.

Udeala O.K., Oneyechi J.O., and Agu S.I., 1980. Preliminary evaluation of dike fat – a new tablet lubricant. J. Pharm. Pharmac., 32, 6-9.