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# SOME PROPERTIES OF BUSH MANGO SEEDNUTS RELEVANT IN CRACKING

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**ABSTRACT**

Some physical and mechanical properties of the seednuts of bush mango fruit (*Irvingia gabonensis*) were determined in order to aid in the design of machines for cracking the seednuts. Experiments were conducted using seednuts obtained from macerated fruits to determine the size, shape, sphericity, geometric mean diameter, density, volume and surface area.

The average moisture content of the test sample was found to be 50.1% w.b. The average major, intermediate and minor diameters were 36.2, 30.1 and 21.1 mm respectively. The results implied that the seednuts have the shape of a scalene ellipsoid with a sphercity of 0.79. The geometric mean diameter of the nuts was 28.3 mm. The average volumes of the seednuts were found to be 11.8 x $10^3$ $mm^3$ by water displacement method and 12.4 x $10^3$ $mm^3$ when computed using axial dimensions and no significant difference existed between the values obtained from the two methods at 95% level. The surface areas obtained experimentally and using axial dimensions were 32.7 x $10^2$ and 27.3 x $10^2$ $mm^2$ respectively and the values were significantly different at 95% level. An empirical model to predict the surface area of seednuts from axial dimensions was developed and was statistically found to be adequate.

**KEYWORDS;** Physical properties, Bush mango, Size, Shape, Volume and Surface area.

## INTRODUCTION

The bush mango is a fruit found in the tropical forest of the West, East and Central Africa (Nzekwe et al. 2002) and is also known as 'Wild Mango' 'Dika nut' and 'African Mango'. Two species of the fruit are identified as *Irvingia gabonensis* and *Irvingia wombolu* (Etukudo, 2003; Nzekwe et. al., 2002). The fruits are commonly spherical in shape, green in colour when mature and yellowish-green when ripe. It is made up of the epicarp, mesocarp (fruit pulp) and a stony endocarp (seednut), which encloses the soft edible endosperm(kernel). The endocarp has a thick, hard shell which has to be cracked open (shelled) in order to extract the kernel.

In Nigeria these kernels are called 'Ogbono' (Okafor, 1978), 'Apon' and 'Uyo' (Etukudo, 2003) The kernel can be processed into flour by extraction, drying and grinding The ground kernel is added to meat and vegetable dishes as a sauce or for thickening soups and stews. The kernel contains fat, protein, carbohydrate and traces of vitamins A and C (Davis, 1998). It can be pounded, made into light paste and applied on burns, bruises and sprains to enhance healing (Etukudo, 2003). In the processing of the fruits for kernels, the fruits are fermented to obtain the seednuts which are dried to a considerably low moisture content before the kernels are extracted. The drying enables the kernel to shrink away from the shell to reduce kernel breakage during cracking of the seednut (Ladipo and Anegbe, 1995). The existing method of cracking the seednut is manual, where the seednut is split open with a machet or broken in-between two stones. The manual extraction of the kernel is tedious, harzadous and time consuming.

The study of the physical properties of the seednut is necessary in the proper design of machines for the extraction of the kernels Duruaka (1995) studied some physical and mechanical properties of the seednut. He found that the average length was 32.9 mm, width was 25.9 mm and thickness was 17.7 mm. He described the shape of seednuts as oblong and not spherical. The average sphericity and roundness indices were 75.1% and 25% respectively. Ibinabo (2004) measured the size, sphericity and roundness indices of seednuts. The average length, width and thickness were 48.1 mm, 33.3 mm and 19.8 mm respectively. The seednuts had sphericity and roundness indices of 64.4% and 30% respectively. He concluded that the shape of the seednuts was oblong and not completely round. Davis (1998) found that the average length, width and thickness of the seednuts were 42.9 mm, 26.2 mm and 18.4 mm respectively. From the results, he showed that the shape was neither round nor spherical, with a low roundness index of 25% and a sphericity index of 64%.

The size of grains, seeds, nuts and fruits have been described by measuring their principal axial dimensions (Mohsenin, 1980, Oje et.al, 2001). The geometric mean diameters of the axial dimensions have also been shown to be adequate for calculating Reynold's numbers, projected areas and drag coefficients of food grains and nuts. These parameters are necessary for the design of machines for pneumatic conveying and fluidization (Gorial and O' Callaghan, 1990). The shape of an agricultural product can be defined by descriptive terms such as round and approaching spheroid, ovate as egg shaped and elliptical and approaching ellipsoid (Mohsenin, 1980). Shape of grains, pulses and fruits have also been described in terms of their sphericities (Mohsenin, 1980; Koya and Adekoya, 1994). The shape of the seednut is described in terms of the sphericity and the relative values of the axial dimensions.

Sphericity ($S_p$) is defined as the ratio of an equivalent diameter of the solid to the diameter of a sphere of equal volume. Hence for a solid with axial dimensions a, b and c;

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$$Sp = \left[\frac{bc}{a^2}\right]^{\frac{1}{3}} \quad - \quad - (1)$$

where: Sp = Sphericity
a = semi-axis of major diameter
b = semi-axis of intermediate diameter
c = semi -axis of minor diameter

The volume V of a solid can be determined by liquid displacement method following Archimede's principle (Mohsenin, 1980). It can also be calculated by obtaining the axial dimensions of a solid. Hence, for a triaxial ellipsoid;

$$V = 4/3\pi\, abc \quad - \quad - \quad - \quad (2)$$

The surface area S of an agricultural product is necessary for the design of machines for handling and processing of the product. It can be determined experimentally or by obtaining the axial dimensions. For a scalene ellipsoid;

$$S = 4\pi\left(\frac{a^pb^p + a^pc^p + b^pc^p}{3}\right)1/p \quad - \quad - (3)$$

where: a, b, c, are semi-axes of major, intermediate and minor diameters, p = 1.6075 which yields a relative error of less than 1.061% by Knud Thomsen's formula(Ellipsoid, 2007).

Density is defined as the ratio of the mass of a sample to the solid volume. The liquid displacement method, following Archimede's principle, has been used in determining densities of agricultural products (Mohsenin, 1980). Density of a nut is required in the computation of aerodynamic drag (West, 1972) and in estimating its terminal velocity (Gorial and O'Callaghan, 1990).

This paper presents results on the determination of the size, shape, mass, density, volume and surface area of the seednuts of bush mango. An empirical model was developed to predict the surface area of seednuts from the axial dimensions.

## MATERIALS AND METHOD

Bush mango fruits were bought from the local market in Abak in Akwa Ibom State, Nigeria. The fruits were placed on the floor for 12 days to ferment and then macerated in a pool of water to obtain clean seednuts. The seednuts were wiped dry and numbered for easy identification. The moisture content of the seednuts were then determined using the oven method, drying at 130°C for 48 hours as specified for unground grains and seeds (ASAE 1998). Ninety randomly chosen seednuts were used for the experiments.

A vernier caliper was used to measure the major diameter, intermediate diameter and minor diameter of each seednut in order to determine its size and shape. Each seednut was weighed to ± 0.01g using a digital weighing balance to find the average mass of each seednut. The actual volume of each seednut was determined using water displacement method. Each value was also determined using the three axial dimensions of an ellipsoid and the two values compared. The surface area of each seednut was determined by wrapping polyethylene paper around the surface of the seednut, and cutting it off at the point of complete enclosure of the seednut The paper was then unwrapped and spread across on a graph paper for surface area determination. Each value was also determined using the formula for an ellipsoid and the values compared.

An equation was developed to predict the surface area of seednuts based on the axial dimensions. Simplifying equation (3) for surface area gives

$$\left[\frac{S}{4\pi}\right]^p = \frac{a^pb^p + a^pc^p + b^pc^p}{3} \quad - \quad - \quad (4)$$

Let $\log A = \frac{a^pb^p}{3}$, $\log B = \frac{a^pc^p}{3}$ and $\log C = \frac{b^pc^p}{3}$

Then, equ. (4) becomes $\left[\frac{S}{4\pi}\right]^p = \log(ABC) \quad (5)$

Therefore $S = \frac{4\pi}{p}\log(ABC) \quad - \quad - \; - \quad (6)$

The regression model used in the computation of surface area was in the form;

$$S = n + my \quad -(7)$$

where: y = log (ABC) as shown above
n and m are constants.
S = surface area obtained experimentally

## RESULTS AND DISCUSSION

The moisture content (percent wet basis) of the seednuts at the time of experiments ranged from 47.9 to 52.1 The average moisture content was found to be 50.1% w. b.
The ranges of the major diameter is 27.2 to 45.9 mm, intermediate diameter is 21.6 to 42.0 mm and minor diameter is 17.0 to 35.0 mm. The average axial dimensions of the seednuts are shown in Table 1 The sphericities of the seednuts ranged from 0.62 to 0.88. The average value was found to be 0.79 as shown in Table 1 The axial dimensions are distinctively different, this implies that the shape of bush mango seednuts is in the form of a scalene ellipsoid with a sphericity of 0.79 The range of geometric mean is 22 6 to 36.1 mm and the mean value of 28 32 mm shown in Table 1 The average mass of the seednut is 10.71g The range of mass of seednuts is 6.29 to 20 29 g.

**Table 1:** Physical properties of seednuts

| Properties | Measurement of seednuts |
|---|---|
| Axial dimensions (mm) | |
| Major diameter | 36.15 (5.41)* |
| Intermediate diameter | 30.12 (4.27) |
| Minor diameter | 21.07 (2.91) |
| Geometric mean diameter(mm) | 28.32 (mm) |
| Sphericity | 0.79 |
| Average mass (g) | 10.71 (3.43) |
| Density ($kg/m^3$) | 16.01(2.0) |

* Numbers in parenthesis are the standard deviation.

The range of volumes of seednuts in the water displacement method is $7.0 \times 10^3$ to $20.5 \times 10^3$ $mm^3$. The range of volumes of seednuts using the axial dimensions to compute is $6.1 \times 10^3$ to $24.6 \times 10^3$ mm. The corresponding average values are 11.8 and $12.4 \times 10^3$ mm as shown in Table 2. Statistical analysis (ANOVA) showed no significant difference in the volumes of seednuts in the two methods (Table 3). These results suggest that the axial dimensions can adequately be used to calculate the volumes of seednuts.

**Table 2:** Other properties of seednuts

| Method of determination | Volume ($mm^3$) Range | Volume ($mm^3$) Mean | Surface Area ($mm^2$) Range | Surface Area ($mm^2$) Mean |
|---|---|---|---|---|
| Experimental | $7.0\times10^3 - 20.5 \times 10^3$ | $11.8\times10^3$ | $17.6\times10^2 - 53.0 \times 10^2$ | $32.2\times10^2$ |
| Axial dimensions | $6.1\times10^3 - 24.6\times10^3$ | $12.4\times10^3$ | $16.4\times10^2 - 45.4\times10^2$ | $27.3\times10^2$ |

**Table 3:** ANOVA of some of the physical properties of seednuts

| Dependent Variable | Computed F Value |
|---|---|
| | Source of variation |
| | Methods of determination |
| Volume of seednuts | 0.43 |
| Surface area of seednuts | 10.18* |

• Significant at 95%

The range of surface areas obtained experimentally is $17.6 \times 10^2$ to $53.0 \times 10^2$ $mm^2$. The range determined using the axial dimensions is $16.4 \times 10^2$ to $45.4 \times 10^2$ $mm^2$ The average surface area obtained experimentally was higher ($32.2 \times 10^2$ $mm^2$) compared to the value computed from the axial dimensions($27.3 \times 10^2$ $mm^2$) as shown in Table 2 . Statistical analysis (ANOVA) in Table 3 showed that the surface areas determined experimentally and by formula vary significantly at the 95% level. This implies that the surface area of seednuts can't be adequately determined by axial dimensions alone. A regression model can be used to predict the surface area by axial dimensions.

Model equation for surface area calculation

The regression equation for predicting the surface area of seednuts from axial dimensions is shown below:

$$S' = 1851.4 + 0.08 [\log A + \log B + \log C]$$

i.e $S' = 1851.4 + 0.08 (a^p b^p + a^p c^p + b^p c^p)$ - (8)

where $S'$ = predicted surface area of seednut in $mm^2$
a = semi-axis of major diameter in mm
b = semi-axis of intermediate diameter in mm
c = semi-axis of minor diameter in mm
p = 1.6075.

Table 4 shows the statistical analysis (ANOVA) for the linear effects in equation (8). The F test was used to evaluate the regression of the model. The F-calculated value was 48.1 far higher than the F-tabulated value of 3.96, which showed that the regression was highly significant at 95% confidence level. The coefficient of determination ($R^2$ = 55%) also showed that the model was adequate in predicting the surface area of seednuts if given the axial dimensions.

**Table 4** : Analysis of variance for the filled model to calculate surface area of seednut.

| Source of Variation | Degrees of freedom | Sum of squares | Mean sum of squares | F Value | F tab |
|---|---|---|---|---|---|
| Regression | 1 | $2.86 \times 10^8$ | $2.86 \times 10^8$ | 48. 1 | 3.96 |
| Residual | 88 | $5.24 \times 10^8$ | $5.95 \times 10^6$ | | |
| Total | 89 | $8.10 \times 10^8$ | | | |

**CONCLUSION**

The physical properties of seednuts of bush mango were studied. From the results of this study, the following conclusion are drawn:

(i) The shape of seednuts is elliptical and can be described as scalene ellipsoid because the seednuts have three unequal diameters.

(ii) There was no significant difference in the volumes of seednuts determined experimentally and computed with the axial dimensions. The axial dimension can be used to obtain the volume of seednuts.

(iii) A large significant difference was observed in the surface area of seednuts determined experimentally and computed with axial dimensions. Therefore an empirical model was developed to predict the surface area of seednuts given the axial dimensions.

REFERENCES


ASAE standards, 1998. American Society of Agricultural Engineers. Standard for Moisture Measurement of Unground grain and seeds 5.352, 45th ed. 551 St. Joseph, Mich. USA.

Asoegwu, S. N., 1995. Some physical properties and cracking energy of canophor nut at different moisture content., Int. Agrophysics. Journal 9, pp 131-142

Davis, D D. 1998, Design of *Irvingia gabonensis* seednut cracker. Unpublished project Rivers state University of Science and Technology, Port Harcourt, Nigeria.

Duruaku, J. C. N., 1995. A study of some physical and Mechanical properties of *Irvingia gabonensis* seednut relevant to primary processing. Unpublished Thesis River State University of Science and Technology, Port Harcourt, Nigeria.

Ellipsoid, 2007. In Wikipedia, The Free Encyclopedia from http: //en. Wikipedia. org/wiki/ ellipsiod. Wikipedia Foundation, Inc. USA. pp 1-2.

Etukudo, I., 2003. Ethnobotany conventional and traditional use of plants, Vol. (1) Actual Publishers. Lagos.

Gorial, B. Y and O' Callaghan, J. R., 1990. Aerodynamic properties of grain/straw materials. Journal of Agricultural Engineering Research 46:275-290.

Ibinabo, A. B., 2004. Investigation of mechanical properties of *Irvinga gabonensis*. Unpublished thesis, River State University of Science and technology, Port Harcourt. Nigeria

Ihekoranye, A I and Ngoddy, P O, (1985). Integrated food science and technology for the tropics Macmillan Publisher pp 82 – 93

Ige, M. M , Ogunsua, A. O, and Oke, O. L. (1984). Nutritional properties of the protein of some Nig. Oil seed Journal of African Food Chemistry 32. 822 – 825

Joshi, D. C., Das. S K. and Mukher-jeek, R. K (1993) Physical properties of pumpkin seeds Journal of Agric Engry Research, 45: 219 -229

Koya, O. A. and Adekoya, L. O., 1994. Some physical and aerodynamic properties relevant in destoning some grain crops. Ife Journal of Technology 4 (2) 35-40

Ladipo D. O. and Anegbe, P . 1995 Flowering and fruiting in field grown bush mango (*Irvingia gabonesis* and *Irvingia wombulu*) in South Eastern Nigeria Paper presented at 25th Annual Conference of Genetic Society of Nigeria (14-18 May 1995) pp 1-2

Ladipo, D O., Foundoun, J M and Ganza, N . 1996 Domestication of Bush Mango, (Irvingia species), Some exploitable intraspeutic variations in West Africa FAC/ICRAT. proceeding of an Int conference pp 139-206

Mohsenin, N N , 1980 Physical properties of plant and animal materials, Vol. 1 Gordon and Breach Science Publishers London pp 51-70, 495-520

Nelson, S. O., 2002 Dimensional and Density Data for seeds of cereal grain and other crops. Tans ASAE Vol. 45 (1) 165-170.

Nzekwe, U., Onyekwelu, S. S. C and Umek, V. G., 2002 Improving the germination of *Irvingia gabonensis* var esccelsa seeds. Conf. Proc. of Hort. Cultural Society of Nigeria (HOR TSON) Vol. 7 pp 1-2

Oje, K., Alonge A. F. and Adigun, Y J., 2001. Some engineering properties of shea nut relevant to mechanical processing .Ife Journal of Technology 10(2). 17- 20.

Okafor, J. C., 1978 Varietal Unlimitation in *Irvingia gabonensis* (*irvingiaceal*). Nigeria J of Forestry 4; 80-87

Orji, C. U., 2000. Evaluation of the physical of properties of breadfruit seeds (*Treculia Africana)* necessary for shelling. J. of Agric Engr. and Tech 8, 55 - 58

West, N. L., 1972 Aerodynamic force predictions Transactions of the American Society of Agricultural Engineers 15 (2): 584-587

White, L. and. Abemethy, K., 1996, Guide de la vegetable de la Reserve de la Lope Gabon, ECOFAC