Effect of moisture content on physical properties of bush mango (*Irvingia gabonensis*) nut

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Abstract: The effect of moisture content on some physical properties of bush mango (*Irvingia gabonensis*) nut was studied at four moisture levels in the range of 7.52%-20.6% (d.b). Results showed that the length, width and thickness of nut increased from 37.84 to 50.16 mm, 30.23 to 42.62 mm and 19.25 to 28.15 mm respectively, as moisture content increased in the above range. Nut sphericity decreased from 76.2% to 69.5% as moisture content increased. One thousand seed weight, bulk density, true density and angle of repose increased from 6.634 to 9.158 kg, 756.7 to 1095 kg m^{-3}, 984.4 to 1265.8 kg m^{-3} and 25.3^{o} to 38.9^{o} respectively, in the above moisture range. Static coefficient of friction on different surfaces increased in the order of fiber glass (0.278 to 0.394), metal sheet (0.478 to 0.499) and plywood (0.577 to 0.602) as moisture content increased. Regression analysis showed that all properties followed a linear trend with moisture content.

Keywords: moisture content, dika nut, *irvingia gabonensis*, size, shape, gravimetric, frictional properties

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1 Introduction

Bush mango (*Irvingia gabonensis*) nut is a genius of African and South Western Asia trees in the family of Irvigiaceae. It is also known by some common names as Wild mango, African mango, Bush mango, Bread tree, Dika nut, Odika, Kaka and Etima nut (Burkill, 1994). In Yoruba, it is called *oro*, *Ogbono* in Igbo, *goron or biri* in Hausa and *manguie sauvage or bobo* in French. The tree is valuable for its edible mango like fruit (Figure 1) and termite–resistant wood (Ayuk et al., 1999*).* The fruit comprises of fleshy mesocaarp and the nut (Figure 2) which is made up of a hard shell and flattened kernel (FAO, 1982).

Several reseachers (Dash et al., 2008; Owolarafe et al., 2007; Karimi et al., 2009; Ogunjimi et al., 2002; and Aviara et al., 2014) have investigated the physical properties of different agricultural products for the purpose of utilizing them in the development of processing and storage facilities. Sizes of agricultural products have been determined by measuring the three principal axial dimensions (Dutta et al., 1988). Aviara et al. (1999, 2005 and 2007) studied the variation of the physical properties of guna seeds, sheanut and guna fruits respectively, with moisture and reported that moisture content had marked effect on the properties of the products. True density were investigated by Nelson (1980), Dutta et al. (1988), Oje and Ugbor (1991), Joshi et al. (1993) and Aviara et al. (1999) using either the gas displacement or the water displacement methods, while bulk density has been determined using AOAC (1980) recommended method. Different methods have been used to determine the static coefficient of friction of agricultural products on different structural surfaces such as wood, fibre glass and metal (Lawton, 1988), but the commonly used is the inclined plane method described by Dutta et al. (1988). Aviara et al. (1999) used a specially constucted box with removable front panel to determine

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the angle of repose of guna seeds. The moisture dependent characteristics of physical properties have been shown to have effect on the adjustment and performance of agricultural processing machines (Aviara et al., 1999). Most studies revealed that a range of moisture content usually exists within which the optimum performance of the machine could be achieved. The effect of moisture on physical properties of bush mango nut would therefore be of important consideration in the design of its handling, processing and storage facilities.

Figure 1 Bush mango fruits

Figure 2 Bush mango nuts

The objective of this study was to determine the effect of moisture content on some physical properties of bush mango (*Irvingia gabonensis*) nut. These include the principal axial dimensions, sphericity, true and bulk densities, angle of repose, mass of one thousand nuts and static coefficient of friction on different structural surfaces.

2 Materials and methods

The bulk quantity of bush mango fruits (*Irvingia gabonensis*) used in the tests was obtained from Iware market near Fiditi in Afijio Local Government Area of Oyo State, Nigeria.The fruits were peeled, washed, sun dried and sorted manually to remove all foreign materials and nuts with defects. The nuts were divided into four portions labelled A, B, C and D. Sample A was left at the initial moisture content. The moisture content for other samples was varied by conditioning the samples using the method employed by Aviara et al. (2005) for sheanut. This involved soaking of samples B, C and D in clean water for a period of ½, 1 and 1½ hours respectively, followed by spreading out to dry in natural air, after which the sample were sealed in polythyene bags and kept in a refrigerator for 24 hours. ASAE standards S352.2 (*ASAE Standard*, 2003) for moisture content determination using the oven drying method, was used to determine the moisture content of the samples. Moisture content was then calculated using the following expression:

$$MC = \frac{M_i - M_f}{M_i} \times 100 \qquad (1)$$

where, MC = moisture content, % (d.b); M_i = mass of nuts before oven drying (g) and M_f = mass of nuts after oven drying (g).

Sizes of nuts was determined by measuring the three principal axial dimensions namely major, intermediate and minor diameters of 100 samples of nut which were randomly selected, using digital Vernier calliper reading to 0.01 mm accuracy. The mass of each of the 100 nuts selected was measured using an electric digital weighing balance reading to 0.01 g. Arithmetic mean (AMD), geometric mean (GMD) and equivalent sphere diameter (ESD) were calculated using the following equations:

$$AMD = \frac{(a+b+c)}{3} \qquad (2)$$

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

$$ESD = \frac{6W_{1000}}{1000\rho_t \pi} \qquad (4)$$

where, a= major diameter (mm); b =intermediate diameter (mm); c = minor diameter (mm) and W is mass (g) of sample. Nut sample at initial moisture content was classified into three categories namely large, medium and small based on the major diameter.

The sphericty of nut was determined using the shadowgraph (Figure 3) of 30 nuts traced on graph sheet. The diameters of smallest circumscribing and largest inscribing circles to the shadowgraphs (Mohsenin, 1986) were measured and the sphericity was calculated using the Equation (5):

$$Sphericity,\ S = \frac{d_i}{d_c} \times 100 \qquad (5)$$

where, d_i = diameter of a sphere of the largest inscribing circle (mm); d_c = diameter of the smallest circumscribing circle (mm).

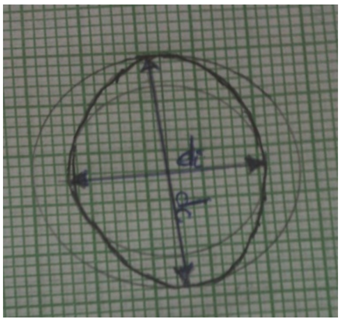

Figure 3 Shadowgraph of bush mango (*irvingia gabonensis*) nut

One thousand – nut mass at each moisture level was obtained using an electronic balance weighing 1,000 nuts to the nearest 0.01 g. Particle density was determined using the water displacement method. Thirty nuts were coated with thin layer of epoxy resin to prevent water absorption during the experiment. Bulk density was determined using the AOAC (1980) method. This was carried out by filling a 500 mL cylinder with nuts to a height of 150 mm and weighing the content. Porosity was calculated from particle and bulk density using the relationship given by Mohsenin (1986) as

$$P = \left(1 - \frac{P_b}{P_i}\right) \times 100 \quad (6)$$

where, P = porosity %; P_b = bulk density (kg m^{-3}); P_i = particles density (kg m^{-3}).

Angle of repose was determined following the procedure employed by Aviara et al. (2005). This involved filling an open-ended box of 15×15×15 cm size having a removable front panel, with sample, on a flat surface. The front panel was quickly removed to allow sample to slide and assumed its natural slope in bulk. The angle of repose was calculated from the ratio of the depth of the free surface of the sample to the horizontal distance from the side having the free surface.

Static coefficient of friction of nut was determined on three structural surfaces namely steel sheet, fiber glass and plywood. The inclined plane method as described by Dutta et al. (1988) and Mohsenin (1986) was used. It involved the placement of a topless and bottomless box on an adjustible tilting surface which was formed with a structural surface. The box was filled with sample and slightly lifted to enable the nuts to be in contact with the surface. The set up was gradually raised with a screw device until the box just started to slide down. The tilt angle was then read from a graduated scale and the tangent of this angle was taken as the static coefficient of friction.

Each experiment was replicated five times and the average of each property at given moisture content was calculated and recorded. Regression equations relating the properties to nut moisture content were established.

3 Results and discussions

The results of bush mango nut size measured at different moisture contents are presented in Table 1. It can be observed from the table that the three axial dimensions increased with increase

In moisture content within the moisture range of 7.52% to 20.6% (d.b). The major, intermediate and minor axial dimensions of the nut increased from 37.84 to 50.16 mm, 30.23 to 42.62 mm and 19.25 to 28.15 mm respectively, in the above moisture range. The arithmetic means of the three principal axes, the geometric mean and the equivalent sphere effective diameters of the nut at different moisture contents also presented in Table 1, increased with increase in moisture content. The arithmetic mean diameter had higher values than the geometric and equivalent sphere effective diameters of the nut. Similar trend was observed by Aviara et al. (2014) for *brachystegia eurycoma* seeds, while Kaleemullah and Gunasekar (2002) reported that there was no significance difference for arecanut kernel.

Table 1 Axial dimensions of (*Irvingia gabonensis*) nuts with different moisture contents

Moisture content (% db)	Major diameter (mm) (a)	Intermediate diameter (mm) (b)	Minor diameter (mm) (c)	Arithmetic Mean diameter (mm)	Geometric Mean diameter (mm)	Equivalent sphere effective dia. (mm)
7.52	37.84±2.93	30.23±2.65	19.25±1.84	29.11	28.02	0.23
10.60	40.15±3.05	32.14±2.93	21.34±2.05	31.21	30.20	0.24
15.62	46.32±3.56	36.25±3.46	25.62±2.60	36.06	35.04	0.24
20.60	50.16±4.38	42.62±4.16	28.15±2.87	40.31	39.19	0.24

The sphericity of nut decreased linearly from 76.2% to 69.5% as moisture content increased from 7.52% to 20.6% (d.b). Shirkole et al. (2011) reported a decrease in sphericity of two varieties of soybean as moisture content increased. The decrease of bush mango nut sphericity with increase in moisture increased could be related to higher increase of nut length as moisture content increased when compared to the nut width and thickness. The variation of sphericity with moisture content shown in Figure 4 can be expressed using the equation:

$$S = 79.51–0.490M, \quad R^2=0.982 \qquad (7)$$

where, M = moisture content in % (d.b); R^2 = coefficient of determination.

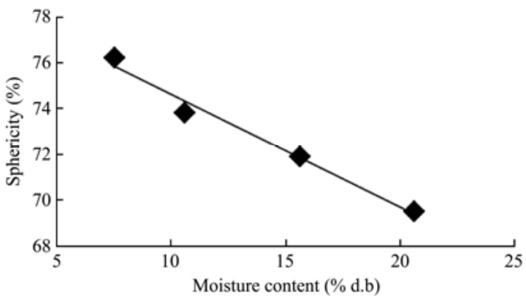

Figure 4 Effect of moisture content on sphericity of bush mango (*irvingia gabonensis*) nut

One thousand seed mass values increased linearly from 6.634 to 9.158 kg as moisture content increased from 7.52% to 20.6% (d.b). Aviara et al. (2014), Karimi et al. (2009) and Tabatabaeefar (2003) reported similar linear increase in one thousand seed mass with moisture content increase. Figure 5 shows the effect of moisture content on one thousand nut mass of bush mango nut and the relationship existing between them can be expressed using Equation (8).

$$W_{1000} = 5.4+0.185M, \quad R^2 = 0.98 \qquad (8)$$

where, W_{1000} = One thousand nut mass (kg).

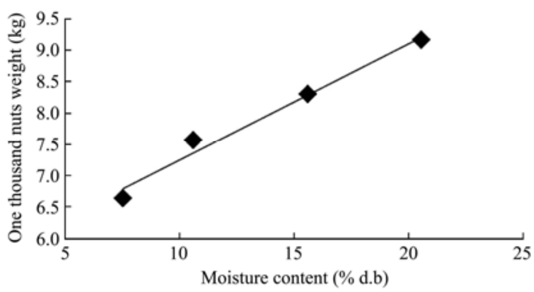

Figure 5 Effect of moisture content on mass of One thousand nuts of bush mango (*irvingia gabonensis*)

The variations of true and bulk densities of bush mango nut with moisture content are presented in Figures 6 and 7. It can be observed from the Figures that true density increased from 984.4 to 1265.8 kg m^{-3} as moisture content increased from 7.52% to 20.6% (d.b). An increase in true density was reported by Aviara et al. (2005), Gharibzahedi et al. (2011), Seifi and Alimardani (2010) for sheanut, castor seed and corn (sc 704) respectively. The relationship existing between true density of nut and moisture content was linear and can be expressed by the following equation:

$$\rho_t = 792.1+23.24M, \quad R^2=0.966 \qquad (9)$$

where, ρ_t = true density, kg m^{-3}.

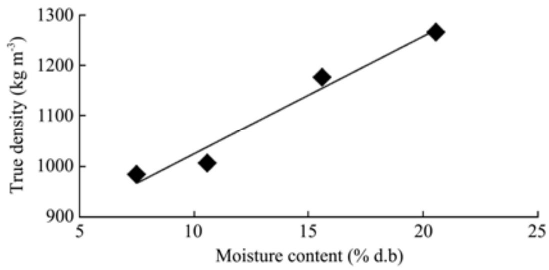

Figure 6 Effect of moisture content on true density of bush mango (*irvingia gabonensis*) nut

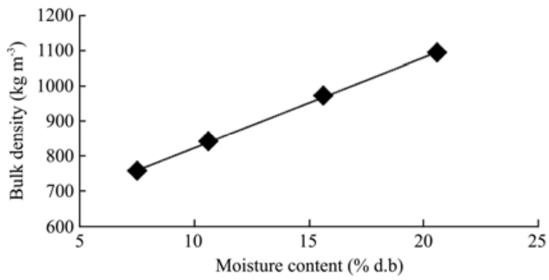

Figure 7 Effect of moisture content on bulk density of bush mango (*irvingia gabonensis*) nut

Bulk density increased from 756.7 to 1095 kg m^{-3} as moisture content increased from 7.52% to 20.6% (d.b). This is at variance with the decrease reported by Aviara et al. (2014), Zewdu and Solomon (2007), and Singh et al. (2010). The relationship between bulk density and moisture content of the nut can be expressed using the following linear equation

$$\rho_b = 564.1+25.89M, \quad R^2=0.999 \qquad (10)$$

where, ρ_b = bulk density (kg m^{-3}).

Angle of repose increased from 25.3^o to 38.9^o as moisture content increased from 7.52% to 20.6% (d.b). The effect of moisture content on angle of repose of bush mango nut is shown in Figure 8 and the relationship existing between them can be expressed using the following linear regression equation:

$$\theta_r = 16.81+1.071M, \quad R^2=0.993 \qquad (11)$$

where, θ_r = angle of repose.

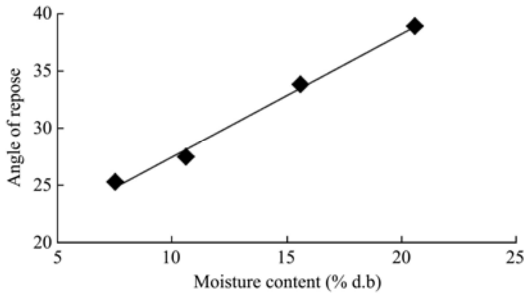

Figure 8 Effect of moisture content on angle of repose of bush mango (*irvingia gabonensis*) nut

The static coefficient of friction of bush mango nut on fibre glass, metal sheet and plywood (Figure 9), shows increase with increase in moisture content from 7.52% to 20.6% (d,b). The maximum values were on plywood (0.577 to 0.602), followed by metal sheet (0.478 to 0.499) and fibre glass (0.278 to 0.394).

The linear relationship that exist between the static coefficient of friction of the nut on a surface and its moisture content can be expressed with the following equations

$$\mu_{fg} = 0.562 + 0.002M, \quad R^2 = 0.985 \qquad (12)$$

$$\mu_{ms} = 0.467 + 0.001M, \quad R^2 = 0.976 \qquad (13)$$

$$\mu_{pl} = 0.369 + 0.001M, \quad R^2 = 0.990 \qquad (14)$$

where, μ_{fg} = fibre glass, μ_{ms} = metal sheet, μ_{pl} = plywood.

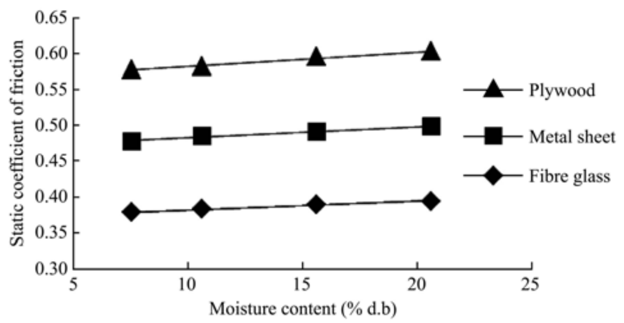

Figure 9 Effect of moisture content on static coefficient of friction of bush mango (*irvingia gabonensis*) nut on different structural surfaces

4 Conclusion

The following conclusions were drawn from the study of some physical properties of bush mango nut within the moisture range of 7.52% to 20.6% (d.b).

a. The length, width and thickness of the nut increased from 37.84 to 50.16mm. 30.23 to 42.62mm and 19.25 to 28.15mm as moisture increased, while sphericity decreased from 76.2 to 69.5% as moisture content increased.

b. True and bulk densities increased linearly from 984.4 to 1265.8 kg m^{-3} and 756.7 to 1095 kg m^{-3} as moisture content increased in the above range.

c. One thousand nut mass increased linearly from 6.634 to 9.158 kg as moisture content increased.

d. Angle of repose was linearly increased from 25.3^o to 38.9^o as moisture content increased.

e. The static coefficient of friction on fibre glass, metal sheet and plywood surfaces showed linear increase with moisture content.

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