International Journal of

Agricultural Research

ISSN 1816-4897

Academic
Journals Inc.

www.academicjournals.com

International Journal of Agricultural Research 6 (12): 848-855, 2011
ISSN 1816-4897 / DOI: 10.3923/ijar.2011.848.855

Some Physical Properties of Gbafilo (*Chrysobalanus icaco*) Fruits and Kernels Preparatory to Primary Processing

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ABSTRACT

Investigation of physical properties of gbafilo (*Chrysobalanus icaco*) is important for the design of appropriate equipment for processing, transporting, cleaning, sorting, packaging and storage processes. The mean length, width and thickness of gbafilo fruit (*Chrysobalanus icaco*) were determined at 8.3% moisture content (d.b.) were 29.64, 23.00, 22.22 mm, respectively. The arithmetic and geometric mean diameter were 24.95 mm and 24.74.22 mm. The sphericity, surface area and as well as 1000 unit mass of gbafilo kernel were 0.82, 1056.70 mm^2 and 2804.64 g. True and bulk densities were 989.19 kg m^{-3} and 652.53 kg m^{-3} for kernel. Angle of static friction of gbafilo fruit and kernel were 19.34° and 17.61°. The static coefficient of friction of plywood structural surface was observed to be the highest followed by galvanized steel sheet and glass. This is an indication that plywood interior lining would not be suitable material for chute design.

Key words: Gbafilo, sphericity, surface area, true density, bulk density

INTRODUCTION

Gbafilo (*Chrysobalanus icaco*) is a medicinal herb. It has different purpose such as therapeutic way to treat undesirable clinical conditions. It is recommended in the treatment of diabetes (Hart, 2005). It is commercially grown in tropical rain forest of some western central African countries such as Nigeria, Ghana, Congo and Senegal. The seeds are economically and medically important been traditionally utilized for preparation special soup, control blood pressure, malaria fever and treatment of stomach disorder.

The physical and mechanical properties of gbafilo are essential for the design of machines for harvesting, transporting, sorting, cleaning, separation, sizing, packaging and processing it into different food. Presently, the machines used for harvesting and processing of gbafilo (*Chrysobalanus icaco*) were designed without taken into consideration physical and mechanical properties, the resulting designs lead to inadequate equipment. Many researchers have reported on the physical and mechanical properties seeds, nuts, kernels and fruits. The physical properties have been studied for various agricultural products by other researchers such as soybean (Manuwa and Afuye, 2004), arigo seed (Davies, 2010), bambara groundnut (Adejumo *et al.*, 2005), caper fruit, *Capparis* spp. (Sessiz *et al.*, 2005), cocoa bean (Bart-Plange and Baryeh, 2003), pigeon pea (Shepherd and Bhardwaj, 1986), locust bean seed (Ogunjimi *et al.*, 2002), wheat (Tabatabaeefar, 2003), pistachio nut and its kernel (Razavi *et al.*, 2007), groundnut (Davies, 2009), Irvingia garbonensis (ogbono) nuts (Zibokere, 2001) cowpea (Davies and Zibokere, 2011) and water hyacinth parts (Davies and Mohammed, 2011).

There is paucity information on physical and mechanical properties of the gbafilo (*Chrysobalanus icaco*) that will assist in the development of appropriate machines. In order to achieve this objective some important physical and mechanical properties of gbafilo (*Chrysobalanus icaco*) fruit and kernel such as axial dimensions, thousand unit mass fruit and kernel, true density, bulk density, porosity, sphericity, static coefficient friction and angle of repose were determined.

MATERIALS AND METHODS

Gbafilo (*Chrysobalanus icaco*) is large, egg-shaped fruit with rough sandpaper-like surface (Fig. 1). The kernel (Fig. 2) which shakes freely inside, is removed and ground for inclusion in pepper soups. The fruits are sold in the markets by traders from the Niger-Delta areas. The gbafilo

Fig. 1: Glafilo fruits

Fig. 2: Gbafilo kernels

fruits were procured for the study from Yenegoa market in Bayelsa State, Niger Delta, Nigeria on 19th April, 2011. The sample were selected and cleaned manually. It was ensured that the fruit were free of dirt, broken ones and other foreign materials. Moisture content was immediately measured on arrival. The experiments were conducted at the moisture content of 8.3% dry basis (d.b).

For this experiment, 100 gbafilo (*Chrysobalanus icaco*) were randomly selected; the length (x), width (y) and thickness (z) and mass of gbafilo were measured using a micrometer screw gauge with a reading of 0.01 mm. The average diameter was calculated by using the arithmetic mean and geometer means of the three axial dimensions. The arithmetic mean diameter, D_a and geometric mean diameter, D_g, of the gbafilo were calculated by using the following relationships (Galedar *et al*., 2008; Mohsenin, 1980):

$$D_a = \frac{(x + y + z)}{3} \tag{1}$$

$$D_g = (x\ y\ z)^{1/3} \tag{2}$$

where, D_a is arithmetic mean diameter (mm) and D_g is geometric mean diameter (mm).

The sphericity (ϕ) (%) was calculated by using the following relationship (Koocheki *et al*., 2007; Milani *et al*., 2007):

$$\Phi = \frac{(x y z)^{1/3}}{L} \tag{3}$$

The surface area S (mm^2) was found by the following relationship given by McCabe *et al*. (1986):

$$S = \pi\, Dg2 \tag{4}$$

The aspect ratio, R_a was calculated by applying the following relationships given by Maduako and Faborode (1990):

$$R = (y/x)\ 100 \tag{5}$$

The unit volume (V) of 100 individual grain was calculated from values of, x, y and z following the formula:

$$V = \frac{\pi\, x\, y\, z}{6} \tag{6}$$

The 1000 unit mass of gbafilo fruit and kernel were determined using precision electronic balance to an accuracy of 0.01 g. To evaluate the 1000 unit mass, 50 randomly selected samples were weighed and multiplied by 20. The reported value was a mean of 20 replications.

The bulk gbafilo fruit and kernel were put into a container with known mass and volume (500 mL) from a height of 150 mm at a constant rate (Garnayak *et al*., 2008). Bulk density was calculated from the mass of bulk fruit and kernel divided by the volume containing mass:

$$\rho b = Mb/ Vb \tag{7}$$

where: ρ_b is bulk density (kg m^{-3}), M_b is mass of fruit or kernel (kg) and V_b is volume of container (m^3).

The true density ρ_t was determined using the unit values of unit volume and unit mass of individual kernel and calculated using the following relationship by Burubai *et al*. (2007):

$$\rho t = M/V \tag{8}$$

where: ρ_t-true density (kg m^{-3}), M-mass of individual fruit or kernel (kg), V-volume (m^3).

The porosity (ε) of the bulk gbafilo was computed from the values of the true density and bulk density of the gbafilo by using the relationship given by Mohsenin (1980):

$$\varepsilon = \frac{\rho^t - \rho_b}{\rho t} 100 \tag{9}$$

where, ε is porosity (%):

ρ_b-bulk density (kg m^{-3})
ρ_t-true density (kgm^{-3})

The 1000 unit mass was determined using precision electronic balance to an accuracy of 0.01 g. To evaluate the 1000 unit mass, 50 randomly selected samples were weighed and multiplied by 20. The reported value was a mean of 20 replications.

The static coefficient of friction for gbafilo was determined with respect to four test surfaces namely: plywood, galvanized steel sheet and glass using Joshi *et al*. (1993). The static coefficient of friction (μ_s) was calculated based on this equation (Mohsenin, 1980):

$$\mu s = \tan \theta \tag{10}$$

The filling or static angle of repose with the horizontal at which the material will stand when piled. This was determined using topless and bottomless cylinder of 0.15 m diameter and 0.25 m height. The cylinder was placed at the centre of a raise circular plate having a diameter of 0.35 m and was filled with gbafilo fruit. The cylinder was raised slowly until it formed a cone on a circular plane. The height of the cone was measured and the filling angle of repose θ_f was calculated by the following relationship (Karababa, 2005; Kaleemullah and Gunasekar, 2002):

$$\theta_f = \tan^{-1} \frac{(2d)}{h} \tag{11}$$

where, h and d are the height and diameter of the cone, respectively

RESULTS AND DISCUSSION

The summary of the results of the physical properties of gbafilo fruit and kernel (*Chrysobalanus icaco*) is shown in Table 1. The average length, width, thickness, arithmetic and geometric mean diameter of gbafilo ranged from 28.50-32.60 mm, 20.50-26.50 mm, 22.80-28.13 mm, 22.22-25.30 mm, 22.46-27.96 mm for the fruit and 21.30-24.70 mm, 15.40-20.80 mm, 15.20-17.90 mm, 16.17-21.13 mm, 15.70-20.95 mm for the kernel respectively. The mean corresponding axial dimension of simarouba fruit as reported by Dash *et al*. (2008) were 21.26 mm, 13.81 mm and 11.03 mm, respectively. Sirisomboon *et al*. (2007) reported the corresponding values of axial dimensions for jatropha seeds as 18.65-21.02, 11.34-11.97 and 8.91-9.58 mm, respectively. A critical view at the axial dimensions of gbafilo, simorouba fruit and jatropha seed revealed that there is significant difference at 0.05%. The axial dimensions play important roles in the design of aperture size of the equipment. It can be deduced from the above data that processing machine designed based on physical properties of gbafilo fruit and kernel may not be suitable for simorouba fruit and as well as jatropha (Dash *et al*., 2008; Mohsenin, 1980). The calculated geometric mean diameter for gbafilo fruit and kernel were 24.74 and 18.34 mm while simarouba fruit and kernel were 14.78 mm and 8.95 mm, respectively. The analysis of variance result revealed that the difference were statistically insignificant at the level of 0.05% for these seeds. The 1000 unit mass of gbafilo fruit and kernel were 3916.21 and 3040.57 while simarouba fruit and kernel, 1120 and 330.26 g, respectively. The obtained result and the corresponding values were significantly differences at 0.05 statistical levels. The mean sphericity of gbafilo fruit and kernel were 0.84 and 0.82.This result is an indication that the shape of gbafilo is very close to sphere. The corresponding values for nutmeg, simarouba fruit and kernel and jatropha seed and kernel were reported by Dash *et al*. (2008) and Burubai *et al*. (2007) were 0.74, 0.69, 065, 0.64 and 0.68 respectively. It is observed from the above result that the sphericity values of gbafilo fruit and kernel were higher than nutmeg, simarouba (fruit and kernel) and jatropha while the sphericity values obtained in simarouba and jatropha were almost similar. Furthermore, the values of sphericity as reported by Jayan and Kumar (2004) for maize, red gram and cotton were 0.621 (±0.065), 0.750 (±0.016) and 0.677 (±0.016). The aspect ratio of fruit is 0.750 and that of kernel is 0.676 and couple with high sphericity values, it means that gbafilo will experience sliding and rolling movement. This behavior is essential for the design and development of hopper.

The average true and bulk density of gbafilo fruit were 813.39 and 497.43 kg m^{-3}. The mean true and bulk density of gbafilo kernel were 986.191 and 652.53 kg m^{-3}. The corresponding true

Table 1: Physical properties of gbafilo fruit and kernel (*Chrysobalanus icaco*) at moisture 8.3% dry basis

	Fruit			Kernel		
Physical properties	Maximum	Minimum	Mean	Maximum	Minimum	Mean
Length (mm)	32.60	28.50	29.64	24.70	21.30	22.48
Width (mm)	25.30	19.40	22.22	17.90	11.80	15.20
Thickness	26.50	20.50	23.00	20.80	15.40	18.06
Arithmetic mean diameter Da (mm)	28.13	22.80	24.95	21.13	16.17	18.58
Geometric mean diameter (Dg) (mm)	27.96	22.46	24.74	20.95	15.70	18.85
Sphericity	0.86	0.79	0.84	0.85	0.74	0.82
Surface area (mm^2)	2455.90	1584..80	1922.90	1378.90	773.37	1056.70
Aspect ratio (%)	77.61	68.07	74.97	72.47	55.40	67.62
1000-unit Mass (g)	4750.47	3603.82	3916.21	3203.47	2567.39	2804..64

Table 2: Gravimetric and frictional properties gbafilo fruit and kernel (*Chrysobalanus icaco*) at moisture 8.3% dry basis at 8.3% dry basis

	Fruit		Kernel	
Properties	Mean	Standard deviation	Mean	Standard deviation
True density (kg m^{-3})	813.39	10.93	986.19	7.47
Bulk density (kg m^{-3})	497.43	6.77	652.53	8.32
Porosity (%)	38.85	0.98	33.83	1.04
Angle of repose	19.34°	0.06°	17.61°	0.08°
Glass	0.48	0.031	0.267	0.028
Galvanised steel sheet	0.59	0.021	0.309	0.012
Plywood	0.63	0.017	0.326	0.010

and bulk density of nutmeg and simarouba fruit and kernel, were 836.54, 488.76 kg m^{-3}, 622.27 and 727.27 kg m^{-3}. The analysis of variance result showed that the difference among true and bulk density values of gbafilo fruit and kernel, nutmeg and simarouba were statistically significant at 0.05 probability level. The mean porosity of gbafilo fruit is 38.85%. The corresponding values of simarouba fruit and kernel were 33.23% (±2.03) and 28.6% (±2.861). Burubai *et al.* (2007) reported porosity of 41% (±4.20) for nutmeg. The porosity of gbafilo, nutmeg and simarouba were statistically difference. The angle of repose of gbafilo fruit was 19.34°(±0.06). The corresponding angle of repose of simarouba fruit and kernel were higher than gbafilo. The corresponding values of angle of repose for maize, red gram and cotton were 22.1°, 28.48° and 21.48°, respectively.

The static coefficient of friction of gbafilo against three different structural surfaces was experimented. The result observed in Table 2 indicated that plywood structural surface had the highest value of static coefficient of friction (0.63) followed by galvanized steel sheet (0.59). Glass as structural surface had the least static coefficient friction (0.48) for gbafilo fruit. There was no significant difference in the coefficient of static friction of wheat in all the surfaces tested while gbafilo experience significant difference in all the tested surfaces.

CONCLUSION

Physical properties of gbafilo were determined at moisture content level of 8.3% (d.b.). The average length, width, thickness, arithmetic and geometric mean diameter, sphericity, surface area and 1000 unit mass were as followed; 19.02 mm, 12.16, 10.19, 13.72, 13.22 mm, 0.78, 601.34 mm^2 and 1124.7 g, respectively.

The porosity and true, bulk density of gbafilo fruit and kernel were 36.31%, 813.39 g^{-3} and 497.43 kg cm^{-3}. The static coefficient of friction for four different structural surfaces, glass, plywood and mild steel were experimentally determined. The highest static coefficient of friction was observed with plywood structural surface, while the least was noticed with glass. Angle of static friction of gbafilo fruit and kernel were 19.34° and 17.61°.

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