Arid Zone Journal of Engineering, Technology and Environment. August, 2015; Vol. 11: 24-36
Copyright© Faculty of Engineering, University of Maiduguri, Nigeria.
Print ISSN: 1596-2490, Electronic ISSN: 2545-5818
www.azojete.com.ng

MOISTURE-DEPENDENT PHYSICAL PROPERTIES OF ÀBÈÈRÈ (*PICRALIMA NITIDA*) SEEDS

Aremu, A. K*. and Duduyemi, A. S.
(Department of Agricultural and Environmental Engineering, University of Ibadan, Ibadan, Nigeria)
*Corresponding author's email and phone no: ademolaomooroye@gmail.com, +2348023843272

Abstract

Some relevant engineering properties of *Àbèèrè* (*Picralima nitida*) seeds are needed for the design of its processing equipments. The geometric, gravimetric and frictional properties of *Àbèèrè* seed in the moisture content ranges of 7.98% - 47.77% (wb) were investigated. The average length, width, thickness, arithmetic and geometric mean diameters, sphericity, surface area, volume, true and bulk densities and angles of repose increased from 28.76 – 30.75mm, 16.18 – 19.62mm, 5.75 – 7.15mm, 16.90 – 19.17mm, 13.81 – 16.11mm,0.48 – 0.53, 600.94 – 817.83mm^2, 443.00 – 717.92mm^3, 2.49×10^{-3} – 2.60×10^{-3}g/mm^3, 1.14×10^{-3} – 1.50×10^{-3}g/mm^{3}and 27.97^o – 30.26^o respectively as the moisture content increased from 7.98% to 47.77%. However, values for porosity decreased from 0.54 – 0.42. The static coefficient of friction of *Àbèèrè* increased linearly over the three material surfaces – plywood, stainless steel and glass – with increasing moisture content from 0.445 – 0.468, 0.286 – 0.384 and 0.357 – 0.389 respectively. The steel surface had the lowest static coefficient of friction whereas the plywood gave the highest value at all moisture content levels. The regression models developed for all the physical properties of the seeds had high coefficient of determination, R^2.

Key words: *Àbèèrè*, physical properties, moisture content, angle of repose, coefficient of friction, porosity.

1. Introduction

Picralima nitida, family *Apocynaceae*, (Common name: *Akuamma plant*; Igbo: *Osi-Igwe*; Yoruba: *Àbèèrè*) grows as either a shrub or small tree up to 22 m tall, with a trunk diameter of up to 16 inches. The tree of this plant grows for about 3 to 4 years before it starts bearing fruits. Its flowers feature a white, creamy or pale yellow corolla. Its fruit is yellow and smooth. Its numerous local medicinal uses include for fever, leprosy sores, stomach, and liver problems and as an anthelmintic, especially against internal worms (Schmelzer and Wageningen, 2008).

It has Berries which have an ellipsoid form, with large size and green in color. When the fruits (berries) mature on the tree, they often fall on the ground and the green pigment on the fruit turns to yellow which will initiate the germination of the seeds in the fruit. Although the berries drop to the ground after maturity, some berries can also ripen on the tree. These berries are also used in traditional medicines for treating typhoid and fight against muscular pain (Oyebadejo *et al.*, 2014). Inside the berries are seeds (Figure 1). The seed is an object of commerce in the local market, and it is collected from the wild thus its availability has been severely threatened.

Dry seeds of the plant, *Picralima nitida* K. Schum, are highly valued in African traditional medicine in the treatment of various human diseases, including diabetes mellitus and obesity (Adeneye and Adeyemi, 2009a; 2009b). The phytochemical analysis of the "*Àbèèrè*" seed revealed the presence of saponins, steroids, tannins, volatile oils, phenols and copious amount of alkaloids (Falodun *et al.*, 2006).

The proximate composition of the *Picralima nitida* seed revealed that the seed contains crude fat content (5.02%), crude protein content (10.20%), ash content (0.88%), crude fibre (5.64%) and moisture content (3.73%) respectively. The seed is a rich source of carbohydrate which was 74.53%. The physicochemical properties of the oil of *Picralima nitida* seed revealed that the oil is brownish in colour and liquid at room temperature. The free fatty acid content was 1.41%. The iodine value which indicates the degree of unsaturation was found to be 136.40 while the refractive index was 1.45. The saponification value was 198.25mg KOH/g. The peroxide value and Unsaponifiable matter were 4.59meqO_2/kg Oil and 1.90%, respectively (Adebowale *et al.*, 2012).

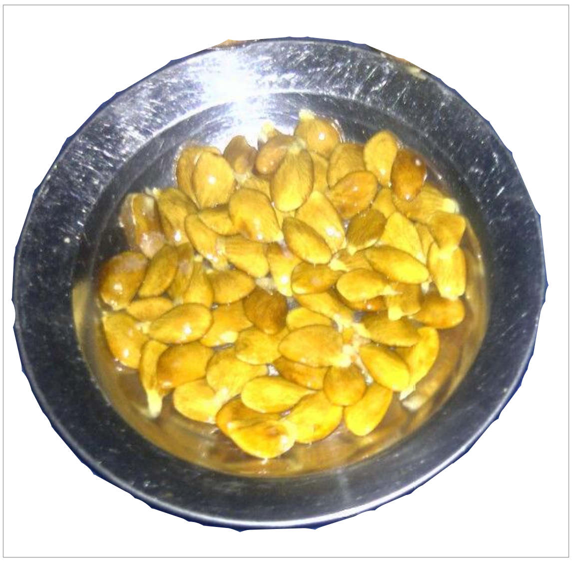

Figure 1: Fresh *Àbèèrè* Seeds

Despite the widespread abundance and traditional use of *Picralima nitida* seeds and with the several research works that have been done on the chemical, phytochemical and toxicological composition of "*Àbèèrè*" seed (*Picralima nitida*) as reported by Falodun *et al.* (2014), review of literatures showed that there is no information relating to the effect of moisture on the engineering properties of the seed.

Presently, the post-harvest handling processes include unit operations such as manual sorting of seeds, manual decorticating of seeds and manual grounding of the dried seeds. The seeds are extracted manually by breaking/cutting the fresh fruit with cutlass and allowing the pulp-covered seed to macerate and washing off in water. Alternatively, the fruits are allowed to decay and then washed off in water using basket, to extract the seeds. The seeds are ground with stone or by pounding in a mortar using wooden pestle. Also, the seeds are being stored using locally woven baskets. These methods of handling and processing seeds are not only time and energy consuming, but also inefficient as the usage of manual labour throughout the processing chain decreases the production efficiency on the farm and sometimes results into wastage of product. This present study is focused on investigating the physical properties of "*Àbèèrè*" (*Picralima nitida*) seeds (axial dimensions, mean diameters, sphericity, surface area, seed mass, bulk density, true density, porosity, angle of repose, and static coefficient of friction) at different moisture levels for design and improvement of relevant machines and facilities for harvesting, storing, handling, processing and packaging. These parameters are important for the design and fabrication of the equipment involved in processes such as seed decorticating and seed oil extraction.

2. Materials and Methods

A bulk quantity of *Picralima nitida* seeds were purchased from a farm in Ile-Ife, Osun State, Nigeria and stored in a laboratory at room temperature before carrying out the experiment. The seeds were cleaned to remove all foreign materials such as dirt, dust, stone and chaff as well as immature and damaged seeds while they were identified at the Department of Botany's Herbarium, University of Ibadan, Ibadan, Oyo State, Nigeria. The following methods were used in the determination of some physical properties of *Àbèèrè* seeds (*Picralima nitida*).

The moisture content of the *Picralima nitida* seeds were obtained according to ASAE Standard S352.3 (1994) by drying the seeds in an electric oven at a temperature of $105(\pm 2)°C$ for 24 hours until there was no change in the seeds' mass at the Department of Animal Science, University of Ibadan, Ibadan, Oyo State and weighing the samples using a digital weighing balance (AND Ek-6100i) reading to 0.01 g. The moisture content of the seeds was varied at five major levels.

The moisture content of the sample in percentage wet basis was calculated using the equation shown below.

$$M_s = \frac{100\ (W_i - W_f)}{W_i} \quad (1)$$

where: M_s is the Moisture content of the seeds (%wb), W_i is the Initial Mass (in grams) and

W_f is the Final Mass after oven drying (in grams).

A method for adjusting the seed's moisture content without damaging its morphology was developed to prepare samples for subsequent tests. After it was soaked in water for 2, 3, 5, 7 and 10 hours, the samples were wrapped in a foil paper and kept in a refrigerator at 5 ˚C (±2 ˚C) for 5 days for the moisture to distribute uniformly throughout the seed (Obi *et al.*, 2014). The moisture content of samples after equilibration was determined before each test was conducted. Accordingly, moisture levels of 7.98, 17.98, 25.11, 37.77 and 47.77% w.b. were obtained. For each test the required quantity of seeds were taken out and allowed to equilibrate with the room temperature. Every test was repeated five times to determine the mean values.

2.1 Determination of size and shape

Fifty *Àbèèrè* (*Picralima nitida*) seeds were randomly selected for each of the moisture content considered and labelled for easy identification. The linear dimensions of the *Àbèèrè* seeds were determined by using a digital Vernier caliper (Carrera Precision Instrument, reading to 0.01 mm) to measure the length, thickness and width of the fruit denoted as *L*, *T* and *W* (all in *mm*) respectively.

2.2 Determination of Mean Diameters

The Arithmetic Mean Diameter (*mm*), D_a, and Geometric Mean diameter (*mm*), D_m, were calculated using equations 2 and 3 respectively..

$$D_a = \frac{L+W+T}{3} \tag{2}$$

$$D_m = \sqrt[3]{LWT} \tag{3}$$

The surface area S in mm^2 was estimated by the relationship given by Asoiro and Anthony (2011) as described by Ajav and Ogunlade (2014):

$$S = \pi {D_m}^2 \tag{4}$$

2.3 Determination of Sphericity

The sphericity is defined as the ratio of the surface area of a sphere with the same volume as the seed to the surface area of the seed (Mohsenin, 1986). The degree of sphericity of the seeds was calculated using equation 5 below as described by Adejumo and Abayomi, (2012).

$$\Phi = \frac{(LWT)^{1/3}}{L} = \frac{D_m}{L} \tag{5}$$

where: Φ is the Sphericity in decimal and other parameters remain as defined above.

2.4 Determination of Densities

The true density of a seed is defined as a ratio of the mass of a sample of a seed to solid volume occupied by the sample (Mohsenin, 1986). The true density of the fruit was determined by weighing the mass of the fruit using a digital weighing balance reading (AND Ek-6100i) to 0.01 g, while its volume was determined by water displacement method (Aremu and Fadele, 2011). The water displacement method was used having ascertained that it takes longer period of time for water to penetrate through the seeds (Obasi *et al.*, 2012). The true density was evaluated by finding the ratio of the true mass to that of the volume.

The bulk density (kg/m^3) is the ratio of mass of a sample of the seeds to its total volume (Mohsenin, 1986). It was determined by filling an empty 250 ml graduated glass cylinder with seeds from a height of about 18 cm, striking the top level and then weighing the contents. The weight of the seeds was obtained by subtracting the weight of the cylinder from the weight of the cylinder with seeds. The volume occupied was then noted (Theertha *et al.,* 2014). The process is replicated five times and the average bulk density for each replication was calculated.

2.5 Determination of Porosity

The porosity of the *Àbèèrè* seeds was estimated from its bulk and true densities using the relationship in equation (6) according to Mohsenin (1986).

$$\varepsilon = (1 - {}^{\rho_b}/_{\rho_t}) \times 100 \tag{6}$$

where: ρ_b and ρ_t are bulk and true densities (all in kgm^{-3}) respectively

2.6 Determination of Static Coefficient of Friction

The static coefficient of friction was determined with the following three structural materials on the tilting table: stainless steel, plywood and glass. The *Picralima nitida* seeds were placed parallel to the direction of motion and the table is raised gently by a screw device (Olaoye, 2000). The angle at which the seeds begin to slide (i.e. angle of inclination) was read from a graduated scale on the tilting table for the three structural materials. The coefficient of friction was calculated as the tangent of this angle as shown in equation 7 below as reported by Ajav and Ogunlade (2014).

$$\mu = \tan\theta \tag{7}$$

where: μ is the static coefficient of friction (decimal), θ is the angle of Inclination (degrees).

2.7 Determination of Angle of Repose

The filling angle of repose of the seeds , θ_f, which is the angle with the horizontal at which the seeds will stand when piled was determined using a topless and bottomless paper cylinder of 15cm diameter and 25cm height as described by Obi *et al.* (2014). The cylinder was placed at the center of a raised circular plate having a diameter of 35cm and filled with the seeds. The cylinder was raised slowly until the seeds formed a cone on the circular plate. The angle of repose was calculated from the measurements of the height (*H*) of the cone formed by the seeds and the Diameter (*D*) of the cone using the relationship below:

$$\theta_f = tan^{-1}(\frac{2H}{D}) \tag{8}$$

where: θ_f is the angle of repose (degrees), *H* is the Height of the cone formed by the seeds and *D* is the diameter of the cone.

2.8 Statistical Analysis

Descriptive statistics were used to analyze the data obtained for each of the properties studied at different moisture content level using Microsoft Excel 2010. Predictive models were developed to establish relationship between the physical properties and moisture content using regression analysis. Analysis of Variance (ANOVA) was used to evaluate the significant effect of moisture content on the properties of the seed.

3. RESULTS AND DISCUSSION

The mean axial dimensions, arithmetic and geometric mean diameters, sphericity, surface area, volume, densities, porosity and angles of repose of *Àbèèrè* seeds samples at five different moisture content levels of 7.98, 17.98, 25.11, 37.77 and 47.77% (wb) are presented in Tables 1a and 1b while the coefficient of static friction of on three different surfaces are shown in Table 1c. Generally, it was observed that the values recorded for most of the physical properties studied increased with increasing moisture content from 7.98 – 47.77% (wb).

3.1 Àbèèrè Seeds Dimensions

Average values of the three principal dimensions of the seeds, namely length, width and thickness, determined in this study at different moisture contents are presented in Table 1a. Each principal dimension increased as the moisture content increased. This could be due to the fact that upon moisture absorption, the grains expanded in length, width and thickness. It was observed that within the moisture content range 7.98% wet basis to 47.77% wet basis, the average length of *Àbèèrè* seeds increased from (28.76±1.82) mm to (30.75±2.71)mm (7% increase in length), the width increased from (16.18±2.30)mm to (19.62±1.62)mm (21%

increase in width), the thickness increased from (5.75±0.75)mm to (7.15±0.73)mm (24% increase in thickness). Similar trends were reported by Altuntas and Erkol, (2010) for shelled and kernel walnuts and Altuntas (2014) for Juniper berries. However, the relationship between the axial dimensions of *Àbèèrè* seeds and the moisture content in wet basis are given by equations 9, 10 and 11:

$$L = 5.017\text{Mc} + 28.335\ (R^2 = 0.998) \tag{9}$$

$$W = 8.859\text{Mc} + 15.126\ (R^2 = 0.918) \tag{10}$$

$$T = 3.457\text{Mc} + 5.575\ (R^2 = 0.953) \tag{11}$$

Table 1a: Some geometric properties of *Àbèèrè* seeds at five moisture contents

M. C. (%wb)	Length (mm)	Width (mm)	Thickness (mm)	Arithmetic Mean Diameter (mm)	Geometric Mean Diameter (mm)	Sphericity
7.98	28.76 (1.82)	16.18 (2.30)	5.75 (0.76)	16.90 (0.81)	13.81 (0.81)	0.46 (0.04)
17.98	29.24 (2.19)	16.72 (1.97)	6.20 (0.75)	17.38 (0.85)	14.09 (0.93)	0.47 (0.05)
25.11	29.55 (2.21)	16.74 (1.40)	6.62 (0.67)	17.63 (0.96)	13.95 (0.95)	0.48 (0.04)
37.77	30.23 (2.54)	18.47 (2.12)	6.88 (0.69)	18.52 (0.96)	15.27 (0.86)	0.51 (0.03)
47.77	30.75 (2.71)	19.62 (1.62)	7.15 (0.73)	19.17 (0.94)	16.11 (0.81)	0.53 (0.05)

Standard deviation values are in parentheses.

Table 1b: Some gravimetric properties of *Àbèèrè* seeds at five moisture contents

M. C. (%wb)	Surface Area (mm^2)	Volume (mm^3)	True Density (x10^{-3}g/mm^3)	Bulk Density (x10^{-3}g/mm^3)	Porosity	Angle of Repose
7.98	600.94 (69.19)	443.00 (75.20)	2.49 (0.88)	1.14	0.54 (0.14)	27.97
17.98	623.48 (59.98)	506.86 (73.12)	2.53 (0.65)	1.27	0.50 (0.13)	28.40
25.11	614.30 (83.86)	546.58 (87.39)	2.59 (0.53)	1.48	0.43 (0.11)	28.54
37.77	732.58 (79.85)	644.28 (98.78)	2.63 (0.40)	1.48	0.44 (0.12)	29.56
47.77	817.83 (80.56)	717.92 (102.06)	2.60 (0.47)	1.50	0.42 (0.10)	30.26

Standard deviation values are in parentheses.

Table 1c: Coefficient of friction of *Àbèèrè* seeds at five moisture contents

M. C. (%wb)	**Coefficient of Friction**		
	Stainless Steel	Glass	Wood
7.98	0.286 (0.024)	0.357 (0.022)	0.445 (0.021)
17.98	0.320 (0.021)	0.365 (0.026)	0.435 (0.032)
25.11	0.370 (0.070)	0.374 (0.026)	0.440 (0.043)
37.77	0.376 (0.067)	0.376 (0.029)	0.452 (0.039)
47.77	0.384 (0.058)	0.389 (0.031)	0.468 (0.034)

Standard deviation values are in parentheses

The ANOVA results presented in Table 2 showed that there were no significant differences ($p<0.05$) in the means of length, width, Geometric Mean Diameters and Sphericity of the seeds across the different moisture contents studied. However, it was revealed that moisture content had significant effect ($p<0.05$) on the thickness and arithmetic mean diameter. This may be due to the fact that the seeds have absorbed enough moisture to cause significant difference in the thickness of the seeds. Thus, the change in moisture content of the seeds will invariably have effect on the thickness of the seeds.

Table 2: ANOVA results or the axial dimensions of *Àbèèrè* seeds at five different moisture contents

M.C.	**Length (mm)**	**Width (mm)**	**Thickness (mm)**	**AMD (mm)**	**GMD (mm)**	**Sphericity**
7.98	28.76^a	16.18^a	5.75^a	16.90^a	13.81^a	0.48^a
17.98	29.24^a	16.72^a	6.20^b	17.38^b	14.09^a	0.47^a
25.11	29.55^a	16.74^a	6.62^b	17.63^b	13.95^a	0.47^a
37.77	30.23^b	18.47^b	6.88^c	18.52^c	15.27^b	0.51^b
47.77	30.75^b	19.62^b	7.15^c	19.17^c	16.11^b	0.53^b

*Means with same letter(s) across columns are not significantly different at $p<0.05$

3.2 Mean Diameters

The average arithmetic and geometric mean diameters are presented in Table 1a. The mean values recorded increased from 16.90 to 19.17 mm and 13.81 to 16.11 mm for the arithmetic and geometric mean diameters respectively as the moisture content increased from 7.98 – 47.77% (wb). It was observed that within the moisture content range, the average arithmetic and geometric increase was 13.41% and 16.65% respectively. This may due to the fact that the Abeere seed expanded more in thickness (24% increase) and width (21% increase) in comparison with the length (7% increase). Such behavior was observed by Sacilik *et al.* (2003) for hemp seed and Shafiee *et al.* (2009) for Dragon’s head seeds.

These properties are particularly important in the design of harvesting, threshing and separating machines (Milani *et al.*, 2007 and Gharibzahedi *et al.*, 2011). However, the relationship between the Arithmetic (D_a) and Geometric (D_g) Mean Diameters with the Moisture Content (Mc) appeared linear as shown in equations 12 and 13:

$$Da = 5.762Mc + 16.347 \quad (R^2 = 0.985) \tag{12}$$

$$Dg = 5.977Mc + 13.012 \quad (R^2 = 0.856) \tag{13}$$

3.3 Sphericity

The average values of the sphericity at the five moisture levels are as presented in Table 1a. The sphericity of the seeds initially decreased from 0.48 to 0.47 as the moisture content increased from 7.98% to 17.98%. However, the sphericity of the seeds increased from 0.47 to 0.53 as the moisture content increased from 25.11% to 47.77% (wb). This is due to the differential dimensional changes in the three axial dimensions. The sphericity of *Picralima nitida* seeds were observed to be lower than that of *Garcinia kola* seed (Igbozulike and Aremu, 2009).

Aremu and Fadele, (2011) reported that the closer the sphericity to 1.0, the higher the tendency of the fruit to roll about any of the three axes and the closer the ratio of thickness to width to 1.0, the higher the tendency to rotate about the major axis. Thus, the values obtained for the sphericity indicates the possibility of the *Àbèèrè* seeds not to roll relatively well but slide where necessary. The sphericity of the seeds has a linear relationship with the moisture content as shown in equation 14.

$$\Phi = 0.0018Mc + 0.4401 \ (R^2 = 0.9709) \qquad (14)$$

Where: $\boldsymbol{\Phi}$= Sphericity; Mc = Moisture Content

Similar trends have been reported by Ndukwu (2009) for *Brachystegia eurycoma* seeds, Aydin et al. (2002) for Turkish mahaleb, Sahoo and Srivastava (2002) for okra seed, Sacilik *et al.*, (2003) for hemp seed, (Coskuner and Karababa, 2007) for flaxseed and Altuntas *et al.* (2005) for fenugreek seed.

3.4 Surface Area and Volume

Surface area of the seed has increased with increase in moisture content as shown in Table1b. The surface area increased from (600.94±69.19) mm^2 to (817.83±80.56) mm^2 as moisture content increases from 7.98% to 47.77%. Similar results were presented by Adejumo and Abayomi, (2012) for unshelled *Moringa oleifera* seed, Obi *et al.* (2014) for Pigeon Pea grown in Nigeria and in reports by Sacilik *et al.* (2003) and Baryeh (2002) for hemp seed and millet, respectively. The surface area affects the rate of moisture loss during drying of seeds, grains and other particulate materials.

The volume also increased from (443±75.20) mm^3 to (717.92±102.06) mm^3 as moisture content increases from 7.98% to 47.77% indicating that the volume-moisture relationship was linear as shown in Table 1b. The volumetric expansion observed may be adduced to moisture absorption which increases the axial dimensions of the grain. The values of the surface area (SA) and volume (V) bear the following relationship with the Moisture Content (Mc) as described by the regression equations 15 and 16.

$$SA = 5.606Mc + 524.65 \ (R^2 = 0.878) \qquad (15)$$

$$V = 694.35Mc + 382.02 \ (R^2 = 0.997) \qquad (16)$$

3.5 True and Bulk Density

The relationship between the true density and moisture content was almost completely linear. The average true density of *Àbèèrè* seeds increased from 2.49×10^{-3} g/mm^3 to 2.60×10^{-3} g/mm^3

as moisture content increased from 7.98% to 47.77% wet basis as shown in Table 1b. A decrease in true density was observed as moisture content increased from 37.77% to 47.77%. This decrease was mainly due to the larger increase in the volume of the grain compared to the lesser increase in the grain mass. A similar trend was reported by Bande *et al.* (2012) for Melon (*Citrullus colocynthis*) seeds. The result of the true density shows that the seed is heavier than water and as such will sink in water. This is useful in the design of cleaning and separation machines to remove chaffs and other materials that can float in water. The true density of *Àbèèrè* seeds is higher than that of Melon seeds (Bande *et al*., 2012) and higher than that reported for *Moringa oleifera* seed (Adejumo and Abayomi, 2012).

As observed from Table 1b, the bulk density of *Àbèèrè* seeds increased with the moisture content from $1.14 \times 10^{-3} g/mm^3$ at 7.98% to $1.50 \times 10^{-3} g/mm^3$ at 47.77%. This pattern was similarly reported by Bande *et al.* (2012) for melon seeds and kernels. The knowledge of bulk density is important in the handling of the seeds in terms of determining the amount and strength of packaging for the seeds.

However, the relationship observed between values of True Density (*TD*) and Bulk Density (*BD)* and the percent moisture content (Mc) of *Àbèèrè* seeds in wet basis are given by equations 17 and 18:

$$TD \times 10^{-3} = 0.0031Mc + 2.4809 \ (R^2 = 0.767) \quad (17)$$

$$BD \times 10^{-3} = 0.009Mc + 1.128 \ (R^2 = 0.775) \quad (18)$$

3.6 Porosity

The porosity of the seeds calculated from the relevant experimental data decreased as shown in Table 1b. The decrease in porosity with increase in moisture content is because an increase in moisture content results in a more significant increase/swelling of the linear dimensions thus reducing the airspaces and giving a more compact arrangement of the seeds invariably reducing the porosity of the seed bulk. Altuntas and Erkol (2010) reported the same trend for shelled and kernel walnuts and Adejumo and Abayomi, (2012) reported the same trend for *Moringa oleifera* seed. However, the values of porosity for *Àbèèrè* seeds fall within the same range of values obtained for Melon (Bande *et al.*, 2012).

The porosity is the most important factor for packing and it affects the resistance to airflow through bulk seeds. The linear relationship between porosity (P) and moisture content is revealed below.

$$P = -0.0029Mc + 0.5444 \ (R^2 = 0.760) \quad (19)$$

3.7 Angle of Repose

The filling angle of repose increased with increase in moisture content of the *abeere* seeds. The mean values of the filling angle of repose was found to increase from 27.97^o to 30.26^o as the moisture content increases from 7.98% to 47.77% w.b (Table 1b). This increasing trend of the filling angle of repose could be attributed to the surface tension caused by the layer of moisture surrounding the seeds. This trend was similarly reported by Ahmadi *et al.*, (2009) for Fennel Seed (*Foeniculum vulgare*)

The values of the angle of repose (AOR) bear the following relationship with the Moisture Content (Mc) as described by the regression equation below.

$$AOR = 5.851\text{Mc} + 27.346 \ (R^2 = 0.960) \quad (20)$$

Singh and Goswami (1996), Nimkar and Chattopadhyay (2001), Baryeh (2002), Amin et al. (2004) and Altuntas *et al.* (2005) also reported a linear increase in angle of repose with increase in the moisture content for cumin seed, green gram, millet, lentil and fenugreek, respectively.

3.8 Coefficient of Friction

It was observed that the coefficient of friction of the *abeere* seeds increased with an increase in moisture content on all the three surfaces studied - plywood, Stainless Steel and glass. The increase in coefficient of friction with an increase in moisture content on all surfaces could be attributed to the increased adhesion between the seed and all the material surfaces at higher moisture content as well as due to the increase in the size of the seed as reported by Obi et al. (2014). The coefficient of friction increased from 0.286 to 0.384, 0.357 to 0.389 and 0.445 to 0.468 for stainless steel, glass and plywood respectively as shown in Table 1c. It was however observed that the highest coefficient of friction of the *abeere* seeds was obtained on plywood and least on glass and stainless steel. Ajav and Ogunlade, (2014) reported that the least static coefficient of friction may be owing to smoother and more polished surface of the glass and stainless steel than the other material used. Altuntas and Erkol, (2010) and Ajav and Ogunlade, (2014) reported the same trend that coefficient of friction increases as the moisture content increase for shelled and kernel walnuts and Ginger (*Zingiber officinale*) respectively.

However, the values of the Coefficient of Friction (COF) on all the three surfaces bear the following relationship with the Moisture Content (Mc) as described by the regression equations 21, 22 and 23.

$$COF_{wood} = 0.0007\text{Mc} + 0.4303 \ (R^2 = 0.643) \quad (21)$$

$$COF_{glass} = 0.0007\text{Mc} + 0.3518 \ (R^2 = 0.947) \quad (22)$$

$$COF_{steel} = 0.0025\text{Mc} + 0.2801 \ (R^2 = 0.834) \quad (23)$$

4. Conclusion

The results showed that the principal dimensions of the seeds increased with respect to moisture content. However, the true density of the seeds does not have a linear relationship with moisture content. The bulk density and filling angle of repose of the seeds however increased with increased in moisture content. The porosity of the seeds decreased with increase in moisture content. Although, the coefficient of friction of the *Àbèèrè* seeds increased with an increase in moisture content on all the three surfaces studied, it was however observed that the highest coefficient of friction of the *Àbèèrè* seeds was obtained on wood and least on glass and stainless steel. The physical properties of Abeere seeds have been determined, providing the baseline data needed for its machine design.

References

Adebowale, AY., Adewuyi, A. and Adebowale, KO. 2012. Lipid composition and molecular speciation of The Triacylglycerol of the oil of Picralima nitida. GIDA, 37 (1): 1-7.

Adejumo, BA. and Abayomi, DA. 2012. Effect of moisture content on some physical properties of *Moringa Oleifera* seed. IOSR Journal of Agriculture and Veterinary Science, 1(5): 12-21.

Adeneye, AA. and Adeyemi, OO. 2009a. Hypoglycaemic effects of the aqueous seed extract of Hunteria umbellata in normal and glucose- and nicotine-induced hypoglycaemic rats. International Journal of Applied Research in Natural Products, 2(1): 9-18.

Adeneye, AA. and Adeyemi, OO. 2009b. Further evaluation of antihyperglycaemic activity of Hunteria umbellata (K. Schum) Hallier f. seed extract in experimental diabetes. Journal of Ethnopharmacology, 126(2): 238-243.

Ahmadi, H., Mollazade, K., Khorshidi, J. and Mohtasebi, SS. 2009. Some physical and mechanical properties of Fennel seed (*Foeniculum vulgare*). Journal of Agricultural Science, 1(1): 66-85.

Ajav, EA. and Ogunlade, CA. 2014. Physical properties of Ginger (Zingiber Officinale). Global Journal of Science Frontier Research: D Agriculture and Veterinary, 18(8): 1-8.

Altuntas, E., Ozgoz, E. and Taser, OF. 2005. Some physical properties of fenugreek (Trigonella foenum-graceum L.) seeds. Journal of Food Engineering, 71: 37–43.

Altuntas, E. and Erkol, M. 2010. Physical properties of shelled and kernel walnuts as affected by the moisture content. Czech Journal of Food Science, 28: 547–556.

Altuntas, E, 2014. The geometric, volumetric and frictional properties of Juniper berries. American Journal of Food Science and Nutrition Research, 2(1): 1-4.

Amin, MN., Hossain, MA. and Roy KC. 2004 Effect of moisture content on some physical properties of lentil seeds. Journal of Food Engineering, 65: 83–87.

Aremu, AK. and Fadele, OK. 2011. Some physical properties of Doum Palm fruit (*Hyphaene thebaica*). African Journal of Agricultural Research, 6(15): 3597-3602.

ASAE. 1994. Moisture measurement-ungrounded grains and seeds. In: ASAE Standards 1994, 469 St. Joseph, MI.

Asoiro, FU. and Anthony, OA. 2011. Determination of some physical properties of African Yam Beans. The Pacific Journal of Science and Technology, 12(1): 374-380.

Aydin, C., Ogut, H. and Konak, M. 2002. Some physical properties of Turkish Mahaleb. Biosystems Engineering, 82: 231–234.

Bande, YM., Adam, NM., Azmi, Y., and Jamarei, O. 2012. Variation of physical properties of Egusi Melon (Citrullus Colocynthis Lanatus Var. Lanatus) seeds and kernels with moisture. International Journal of Basic and Applied Sciences, 12(05): 65-74.

Baryeh, EA. 2002. Physical properties of millet. Journal of Food Engineering, 51: 39–46.

Coskuner, Y. and Karababa, E. 2007. Some physical properties of flaxseed (*Linum usitatissimum* L.). Journal of Food Engineering, 78: 1067–1073.

Falodun, A., Erharuyi, O., and Langer, P. 2014. Medicinal uses, phytochemistry and pharmacology of Picralima nitida (Apocynaceae) in tropical diseases: A review. Asian Pacific Journal of Tropical Medicine, 7(1): 1-8.

Falodun, A., Nworgu, ZAM. and Ikponwonsa, MO. 2006. Phytochemical components of *Hunteria umbellata* and its effect on isolated non pregnant rat uterus in oestrus, Pakstanian Journal of Pharmaceutical Science 19(3): 256-258.

Gharibzahedi, SMT., Mousavi, SM. and Ghahderijani, M. 2011. A survey on moisture-dependent physical properties of castor seed (Ricinus communis L.). Australian Journal of Crop Science, 5(1):1-7.

Igbozulike, AO. and Aremu, AK. 2009. Moisture dependent physical properties of *Garcinia kola* seeds. Journal of Agricultural Technology, 5(2): 239-248.

Schmelzer, GH and Wageningen, AG. (2008). Plant Resources of Tropical Africa; Medicinal Plants, 11(1): 336-337.

Milani, E., Seyed, M., Koocheki, A., Nikzadeh, V., Vahedi, N., Moeinfard, M. and Gholamhosseinpour, A. 2007. Moisture dependent physical properties of cucurbit seeds. International Agrophysics, 21: 157-168.

Mohsenin, NN. 1986. Physical Properties of Plant and Animal Materials. Gordon and Breach Science Publishers, New York.

Ndukwu, MC. 2009. Determination of selected physical properties of *Brachystegia eurycoma* seeds. Research in Agricultural Engineering, 55(4): 165-169.

Nimkar, PM. and Chattopadhyay, PK. 2001. Some physical properties of green gram. Journal of Agricultural Engineering Research, 80: 183–189.

Obasi, NA., Okorie, UC., Enemchukwu, BN., Ogundapo, SS. and Otuchristian, G. 2012. Nutritional evaluation, phytochemical screening and antimicrobial effects of aqueous extract of *Picralima nitida* peel. Asian Journal of Biological Sciences, 5(2): 105-112.

Obi, FO., Anyadike, CC., and Onyeke, CO. 2014. Moisture-dependent physical properties of pigeon pea grown in Nigeria. World Applied Sciences Journal, 31 (8): 1396-1405.

Olaoye, JO. 2000. Some physical PProperties of Ccastor nut relevant to the design of processing equipment. Journal of Agricultural Engineering Research, 77(1): 113-118.

Oyebadejo, SA, Solomon, IP., and Idiong, Jr. JU. 2014. Histomophological effect of chronic oral consumption of ethanolic extract of Picralima Nitida (Akuamma) seed on the caudal epidydimis of adult wistar rats. Journal of Biology, Agriculture and Healthcare, 4(23): 59-66.

Sacilik, K., Ozturk, R. and Keskin, R. 2003. Some physical properties of hemp seed. Biosystems Engineering, 86 191–198.

Sahoo, PK. and Srivastava, AP. 2002. Physical properties of okra seed. Biosystems Engineering, 83: 441–448.

Shafiee, S., Modares, MA., Minaee, S. and Haidarbigi, K. 2009. Moisture dependent physical properties of dragons head seeds (*Lallemantia iberica*). Agricultural Engineering International: the CIGR Ejournal. Manuscript 1192. Vol. XI.

Singh, KK. and Goswami, TK. 1996. Physical properties of cumin seed. Journal of Agricultural Engineering Research, 64: 93–98.

Theertha, DP., Sujeetha, JARP., Kavitha Abirami, CV. and Alagusundaram, K. 2014. Effect of moisture content on physical and gravimetric properties of black gram (*Vigna Mungo* L.). International Journal of Advancements in Research and Technology, 3(3): 97-104.