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Review Paper

Some physical properties of groundnut (*Arachis hypogaea* Linn) seeds: A review

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Abstract. The physical properties of groundnut seeds such as length, width, thickness, mass, size, shape, surface area, volume, aspect ratio, sphericity, true density, bulk density, porosity and angle of repose were reviewed. The methods of determination of these properties and their applications in food processing technology were discussed. Some researches about the effects of moisture on physical properties of groundnut seeds were also studied. These physical characteristics which when measured are relevant for the design and development of harvesting, seed sizing, handling, processing grading machines and in their separation from undesirable materials and decorticating and storage equipment for groundnut seeds.

Keywords: Groundnut, physical properties, physical dimension, processing equipment.

INTRODUCTION

Groundnut or peanut (*Arachis hypogaea* Linn, *Palpilionoideae* [*Fabaceae*/*Leguminosae*]) is a native of Brazil and believed to have been introduced into Africa by the Portuguese (Anyanwu et al., 2001; Singh, 2009). The introduction of peanut (*Arachis hypogaea* L.) cultivation coincides with the expansion of the Mediterranean civilizations. Peanut is an important crop grown in the world, originating in South American, and it spreads beyond the Mediterranean, such as China, Africa, Indian, Japan and United States of America (Zhao et al., 2012). It is grown in nearly 100 countries on six continents between 40° North and 40° South of the equator on nearly 24.6 m ha, with a production of 41.3 m.t. and productivity of 1676 kg ha^{-1} in 2012. China, India, Nigeria, USA and Myanmar are the leading groundnut producing countries in the world. Asia, with 11.6 m ha (47.15%), and Africa, with 11.7 m ha (47.56%), holds maximum global area under groundnut production. Developing countries in Asia, Africa and South America account for over 97% of world groundnut area and 95% of total production. However, the productivity of Asia (2217 kg ha^{-1}) and Africa (929 kg ha^{-1}) is comparatively lower than that of America (3632 kg ha^{-1}) (FAOSTAT, 2014; Ajeigbe et al., 2015). Groundnut is usually grown as a smallholder crop in the semi-arid tropics under rain-fed conditions. Groundnut is now widely cultivated throughout the tropical, sub- tropical and temperate countries of Africa, Asia, North and South America. The major groundnut producing countries in West Africa are Nigeria, Gambia, Togo, Republic of Benin, Ghana, Ivory Coast, Liberia, Chad, Niger, Senegal, Mali and Upper Volta Guinea. As at 2008/2009, Nigeria is the largest producer of groundnut in Africa and fourth in the world (Ajeigbe et al., 2015). Nigeria, it is both a rainforest and savanna crops where the bulk in grown in latter zone than former zone (Opeke, 2006). Groundnut is a very popular crop in Nigeria; cultivated across the nation. It is well known to indigenous people and put into series of uses by various indigenous inhabitants (Adejumo et al., 2005).

The physical properties of groundnut seeds such as mass, size, shape, surface area, volume, aspect ratio, sphericity, true density, bulk density, porosity and angle of repose are those characteristics which when measured are relevant to the design and development of harvesting, handling, processing and storage equipment for that particular material (Burubai and Amber, 2014; Abioye et al., 2016). These properties describe the physical state of the material at any given condition and time. The mass, size, and shape are essential for sorting, grading, and various separation operations (Zare et al., 2013). Pressure loads on storage structures is also dependent on angle of repose and frictional coefficients on bin wall materials (Burubai and Amber, 2014).

A rational approach to the design of groundnut processing machinery, equipment and facilities will involve a theoretical basis, laying down the mathematical and mechanical foundations that will enable the coupling of the physical properties of groundnut seeds with the characteristics of the machinery, equipment, facilities, and so forth. The physical properties do not only constitute the basic engineering data required for machine and equipment design, but they also aid the selection of suitable methods for obtaining those data (Akcali et al., 2006).

The fundamental properties of groundnuts under consideration will be their geometrical shape and the related dimensions, specific mass and friction coefficients of hulled groundnuts, kernels and shells. Specific mass and friction coefficient depend primarily on the geometrical shape and the relevant dimensions. It is necessary to know specific mass for a number of good reasons. First of all, specific mass is an essential parameter for the storage, handling and processing of the product (Akcali et al., 2006). For instance, the methods of processing like sieving, cleaning, and separating into several components may be based upon the differences of specific masses. Data on specific mass are also required for the dimensioning of warehouses, feeding units, as well as for determining capacities and mass flow rates in several processing units, for estimating critical or terminal velocities, and for evaluating inertia of the product (Akcali et al., 2006). Some examples are the estimation of power requirements for the transportation of the product; realization of the velocity and the sieving control. The calculating of the lateral pressure in a silo wall will necessitate the data on frictional properties including friction coefficients; internal friction angle and angle of repose. Such data will not only affect the shapes and dimensions of storage, flow characteristics in the handling and methods of processing units but also overall costs (Akcali et al., 2006). During the processing, properties like densities, thermal conductivity, heat capacity present substantial changes depending on the composition, the temperature and the physical structure of the food (Nesvadha, 2005; Figura and Teixeira, 2007).

The processing operations are predominantly done manually in Nigeria. The manual processing operations of groundnut are time consuming and laborious, the condition prevalent at this level is generally unsanitary and inherent unhygienic conditions. There has been an urgent need to design and develop machinery used in processing groundnuts industrially, which, in turn requires knowledge of their physical properties (Akcali et al., 2006). The knowledge of physical and mechanical properties of groundnut like any other biomaterial is fundamental because it facilitates the design and development of equipment for harvesting, handling, conveying, cleaning, delivering, separation, packing, storing, drying, mechanical oil extraction and processing of agricultural products (Davies, 2009).

For years, the physical properties of agricultural products have been of interest to many researchers. They have reported physical properties of seeds, nuts, kernels and fruits such as maize (Bart-Plange et al., 2005), arigo seeds (Davies, 2010), tef seed (Ozarslan, 2002), chick pea and wheat grains (Aydins, 2002), lentil seeds (Bagherpour et al., 2010 and Ozturk et al., 2010), soybeans (Davies and El-Oken, 2009), chia seeds (Ixtaina et al., 2008), rice (Correa et al., 2007), raw and parboiled paddy (Reddy and Chakraverty, 2004), hemp seeds (Sacilik et al., 2003), flax seeds (Singh et al., 2012) and corn seeds (Babic et al., 2013). Other researchers include soybean (Manuwa and Afuye, 2004), Bambara groundnut (Adejumo et al., 2005), cocoa bean (Bart-plange and Baryeh, 2003), locust bean seed (Ogunjimi et al., 2002), wheat (Tabatabaeefa, 2003), pigeon pea (Baryeh and Mangope 2002) and pistachio nut and its kernel (Razari et al., 2007).

This paper is aimed at reviewing some physical properties of groundnut seeds as well as outlines the determination of these properties and their application in food processing technology. It will be relevant for the design and development of harvesting, seed sizing, handling, processing grading machines and in their separation from undesirable materials and decorticating and storage equipment for groundnut seeds.

DETERMINATION OF PHYSICAL PROPERTIES OF GROUNDNUT SEEDS

Presently, the equipment used in processing groundnut have been generally designed without taken into cognizance to the physical properties of groundnut which include the size, mass, bulk density, true density, sphericity, porosity, coefficient of static friction and angle of repose and resultant systems leads to reduction in working efficiency and increase in product losses (Manuwa and Afuye, 2004; Razari et al., 2007).

Abioye et al. (2016) determined the effect of moisture contents of food materials on the physical properties of food materials. They prepared samples of the desired moisture contents by adding the amount of distilled water and calculated from the following relation given by Sacilik et al. (2003):

$$Q = \frac{W_i(M_f - M_i)}{100 - M_f} \quad (1)$$

Where

W_i = the initial mass of sample in kg, M_i = the initial moisture content of sample in % W. B.
M_f = the final moisture content of sample in % W. B.

Abioye et al. (2016) then poured the samples into separate polyethylene bags which were tightly sealed. The samples were kept at 5°C in a refrigerator for a week to enable the moisture to distribute uniformly throughout the samples. The required quantity of the seed was taken out of the refrigerator and allowed to equilibrate at the room temperature for about 2 hours (Coskun et al., 2006) before experiment.

Axial dimensions

A sample of 100 seeds is randomly selected in order to determine the average size of the seeds. According to Davies (2009), the samples were selected and cleaned manually. It was ensured that the grains were free of dirt, breakages and other foreign materials. The grains were kept in the room temperature for two days. Moisture content was immediately measured on arrival. The experiments were conducted at the moisture content of 7.6% dry basis (d. b). The three linear dimensions such as length (L), width (W) and thickness (T) are measured using a micrometer screw gauge (least count 0.01 mm) as described by de Figueiredo et al. (2011).

Measurements and observations have shown that among the basic dimensions (the width and thickness) of the groundnut exhibit only small differences. Akcali et al. (2006) reduced width and thickness into a single parameter, which will also provide convenience for the theoretical approaches, thus making it possible to represent groundnuts geometrically with length (L) and diameter (d) parameters. Akcali et al. (2006) formed a geometrical model, which is sufficient to describe the groundnut. It is considered as being composed of a cylinder of finite length in the middle and two hemispheres of the same cylinder radius in the ends. One advantage of this model is that it applies to both shell and kernel. The volume of this model, V_m was calculated by Akcali et al. (2006).

$$V_m = \frac{\pi d^2}{2}\left[\frac{d}{3} + \frac{L-d}{2}\right] \quad (2)$$

Geometric properties

Geometric properties of grains are fundamental because they determine interactions between and among particles and with the surrounding air. These interactions influence almost all the engineering properties of grains that must be considered in the design and evaluation of grain storage and handling systems (de Figueiredo et al., 2011). The geometric mean (D_g), the sphericity (Φ) and surface area (S) defined as the ratio between the surface of the sphere having the same volume as that of the seed and the surface area of the seed were determined using the following expressions by Varnamkhasti et al. (2008) and Abioye et al. (2016) respectively.

Average diameter: The average diameter is 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 groundnut were calculated by using the following relationships (Galedar et al., 2008).

$$D_a = \frac{L+W+T}{3} \quad (3)$$

Geometric mean diameter: The geometric mean diameter is useful for the evaluation of the projected area of a particle moving in the turbulent or near-turbulent area of an air stream. Hence, it is a useful parameter in design of separation systems for the seeds from extraneous materials (Gharibzahedi et al., 2010).

$$D_g = (LWT)^{1/3} \quad (4)$$

Where
D_a – Arithmetic mean diameter (mm), D_g – Geometric mean diameter (mm), L – Length (mm), W- Width (mm), T - Thickness (mm).

Sphericity: Sphericity is an expression of a solid shape relative to that of a sphere of the same volume. The values of sphericity show that the seed are nearly spherical in shape and it will roll easily on surface especially in hoppers and dehulling equipment. High sphericity and aspect ratio is an indication of the seeds tending to a spherical shape. These properties are useful in the design of dehulling equipment. The sphericity (Φ) (%) was calculated by using the following relationships (Koocheki et al., 2007; Milani et al., 2007)

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

$$\Phi = \frac{D_g}{L} \quad (6)$$

Surface area: The surface area S (mm^2) was found by the following relationship given by Davies (2009); Odesanya et al. (2015) and Muhammad et al. (2017).

$$S = \pi D_g^2 \quad (7)$$

$$S = \frac{\pi BL}{(2L-B)} \quad (8)$$

where $B = \sqrt{(WT)}$ (9)

Aspect ratio: The aspect ratio relates the width to the length of the seed which is an indicative of its tendency towards being spherical in shape (Abioye et al., 2016).

The aspect ratio, R_a was calculated by applying the following relationships given by Davies (2009).

$$R_a = \left(\frac{W}{L}\right) 100 \quad (10)$$

Gravimetric properties

The gravimetric properties are the true density, bulk density and the porosity.

***1000 unit mass*:** The 1000 unit mass is determined using precision electronic balance to an accuracy of 0.01 g. To evaluate the 1000 unit mass, 50 randomly selected samples are weighed and multiplied by 20. The reported value is a mean of 20 replications. The bulk grains are put into a container with known mass and volume (500 ml) from a height of 150 mm at a constant rate (Milani et al., 2007). The unit mass of the seed (g) is evaluated from the samples used to calculate the density, dividing the mass of the sample by the number of seeds. The increase in mass may be attributed to the weight increase on absorption of moisture.

***Volume*:** The unit volume of 100 individual grains was calculated from values of L, W and T using the following formula:

$$V = \frac{LWT}{6} \quad (11)$$

***Bulk density*:** The knowledge of bulk density is useful for the design of silos and hoppers for grain handling and storage (Nalladulai et al., 2002) to determine the weight of agricultural/food products that will be held by these containers. Within the moisture range studied by Abioye et al. (2016), bulk density decreases with the increased in moisture level. It could be attributed to the fact that increase in volume may be slightly high when compared with the net increase in mass of the bulk seed. Bulk density is calculated from the mass of bulk grain divided by the volume containing mass. The bulk density is determined by using the mass/volume relationship (Abioye et al., 2016) by filling an empty calibrated plastic container of predetermined volume and tare weight with grains by pouring from a constant height, striking off the top level and weighed.

$$\rho_b = \frac{M_b}{V_b} \quad (12)$$

where: ρ_b - Bulk density (kgm^{-3}); M_b – Mass of seeds (kg); V_b – Volume of container (m^3).

***True density*:** The true density (ρ_t) is defined as the ratio of the mass of the sample to its true volume. The true density was determined according to the method of de Figueiredo et al. (2011) using an electronic balance reading 0.001 g and a pycnometer (water displacement method). The true density ρ_t was determined using the unit values of unit volume and unit mass of individual grain and calculated using the following relationship:

$$\rho_t = \frac{M}{V} \quad (13)$$

where: ρ_t – True density (kgm^{-3}); M – Mass of individual seed (kg); *V* - Volume (m^3).

True density has practical application in determining separation of food product from undesirable materials and cleaning is an important unit operation in food processing (Fellow, 2000). The sinking and floating method is applicable for grain/kernel samples because all the food products (nut, kernels, seeds, fruits etc.) are greater than that of density of water.

***Porosity*:** The porosity of the bulk grain is computed from the values of the true density and bulk density of the grains. The porosity value, defined as the fraction of space in the bulk grain which is not occupied by the grain, is calculated from the following relationship according to Davies (2009) and Abioye et al. (2016).

$$\varepsilon = \left(1 - \frac{\rho_b}{\rho_t}\right) \times 100 \quad (14)$$

Where Є – Porosity (%); ρ_b- Bulk Density (kgm^{-3}); ρ_t- True Density (kgm^{-3})

Static coefficient of friction: Davies (2009) obtained the static coefficient of friction for groundnut seeds with respect to four test surfaces namely plywood, galvanized iron sheet, concrete and glass. A glass box of 150 mm length, 100 mm width and 40 mm height without base and lid was filled with sample and placed on an adjustable tilting plate, faced with test surface. The sample container was raised slightly (5 to 10 mm) so as not to touch the surface. The inclination of the test surface was increased gradually with a screw device until the box just started to slide down and the angle of tilt was measured from a graduated scale. The sample in the container was emptied and refill with a new sample. The static coefficient of friction (ms) was calculated based on this equation from Odesanya et al. (2015) and Muhammad et al. (2017).

$$m_s = tan\,\theta \quad (15)$$

Abioye et al. (2016) determined the static coefficient of friction of a food material by measuring against the three different surfaces (mild steel plate, unsanded plywood and aluminium) using a cylinder of 75 mm diameter and 50 mm depth filled with seeds/kernels respectively. While the cylinder resting on the surface, it was raised gradually until the filled cylinder just started to slide down. Static coefficient of friction was then calculated:

$$\mu = \tan\beta \quad (16)$$

Where: β is the angle of incline.

Filling or static angle of repose: The filling or static angle of repose with the horizontal at which the material will stand when piled. This is determined using topless and bottomless cylinder of 0.15 m diameter and 0.25 m height. The cylinder is placed at the centre of a raise circular plate having a diameter of 0.35 m and is filled with groundnut grains. The cylinder is raised slowly until it formed a cone on a circular plane. The height of the cone is measured and the filling angle of repose θ_f is calculated by the following relationship (Kaleemullah and Gunasekar, 2002; Karababa, 2006; Davies, 2009).

$$\theta_f = tan^{-1}(2H/D) \quad (17)$$

According to Abioye et al. (2016), the dynamic angle of repose was evaluated on three structural surfaces namely: mild steel plate (MS), unsanded plywood (PW) and aluminum surface (AL). Abioye et al. (2016) determined angle of repose by using an empty cylindrical mold of 15 mm diameter and 25 mm height. The cylinder was placed at the surfaces afore-mentioned, filled with food material (seeds, nuts, kernels etc.) and raised gradually until it forms a cone of grains. The angle of repose was calculated from measurements of the height (H) of the free surface of seeds/grains and the diameter (D) of the heap formed using the relationship (Olaoye, 2000).

$$\theta = tan^{-1}\left(\frac{2\pi H}{D}\right) \quad (18)$$

Where: H and D are the height and diameter of the cone, respectively.

SOME PHYSICAL PROPERTIES OF GROUNDNUT GRAINS DETERMINED BY SOME RESEARCHERS

The mean length, width and thickness and their dependence on moisture content were reported by Abioye et al. (2016). The values of these physical dimensions would be an important consideration in the development of seed sizing, grading machines and in their separation from undesirable materials (Ogunjimi et al., 2002) and decorticating equipment.

Abioye et al. (2016) reported that geometric mean diameter, sphericity and surface area increased as moisture content increased. The increase in values of geometric properties might be attributed to its dependence on the three major dimensions of the seed. For moisture range considered by Abioye et al. (2016), all geometric properties presented significant differences ($p \leq 0.05$) with moisture content of the seed except sphericity. A linear increase in true density was observed with increase in moisture content. A similar increasing trend in true density was reported by Coskun et al. (2006) for coffee and sweet corn. The observations of Abioye et al. (2016) may be due to the higher mass increase of nut in comparison with its volume expansion on moisture gain. The geometric mean diameter is useful for the evaluation of the projected area of a particle moving in the turbulent or near-turbulent area of an air stream. Hence, it is a useful parameter in design of separation systems for the seeds from extraneous materials (Gharibzahedi et al., 2010).

The values of sphericity show that the seed are nearly spherical in shape and it will roll easily on surface especially in hoppers and dehulling equipment. High sphericity and aspect ratio is an indication of the seeds tending to a spherical shape. These properties are useful in the design of dehulling equipment. The increase in mass may be attributed to the weight increase on absorption of moisture. The knowledge of bulk density is useful for the design of silos and hoppers for grain handling and storage (Nalladulai et al., 2002) to determine the weight of agricultural/food products that will be held by these containers. Within the moisture range studied by Abioye et al. (2016), bulk density decreases with the increased in moisture level. It could be attributed to the fact that increase in volume may be slightly high when compared with the net increase in mass of the bulk seed.

A linear increase in true density was observed with moisture content. A similar increasing trend in true density was reported by Coskun et al. (2006) for coffee and sweet corn. The observations of Abioye et al. (2016) may be due to the higher mass increase of nut in comparison with its volume expansion on moisture gain. True density has practical application in determining separation of food product from undesirable materials: cleaning is an important unit operation in food processing (Fellow, 2000). The sinking and floating method is applicable for grain/kernel samples because all the food products (nut, kernels, seeds, fruits etc.) were greater than that of density of water.

Firouzi et al. (2009) determined some physical properties of groundnut grains (Table 1) at three different moisture contents 8, 20 and 32% dry basis. According to Firouzi et al. (2009), the angle of repose of groundnut increased in line with increasingly moisture content. The least angle of repose was obtained at the moisture level of 8% (db.). The value (30.3) is slightly greater than that of the average values for medium sizes of groundnuts obtained by Akcali et al. (2006) at the moisture of level of 5% db (26.6 to 29.0%). They also showed that with increasing kernel size, the angle of repose decreased.

According to Firouzi et al. (2009), the amount of static friction coefficient of groundnut increased from 0.35 to 0.69 for wood and from 0.25 to 0.49 for galvanized metal sheet with increased groundnut moisture (8 to 32% db.) level. The kernels may become more adhesive and sliding characteristics decreased with increasing the

Table 1. Means and standard errors of the kernel dimensions at the moisture level of 8% D. B.

Parameters	Means ± Standard Errors
Length (mm)	20.83 ± 1.47
Width (mm)	11.08 ± 0.96
Thickness (mm)	8.94 ± 0.83
Geometric mean diameter (mm)	12.71 ± 0.06
Sphericity (%)	61.12 ± 4.06
Mass (g)	1.11 ± 0.02
Volume (cm^3)	1.16 ± 0.03

Source: Firouzi et al. (2009).

Table 2. Some physical properties of groundnut grains at 7.6% dry basis.

Properties	No. of samples	Minimum	Maximum	Standard deviation
Length (mm)	100	13.05	15.42	1.05
Width (mm)	100	7.25	7.94	0.78
Thickness (mm)	100	7.04	7.57	0.03
1000 gram mass (g)	50	360.54	380.5	10.54
Arithmetic mean diameter (mm)	100	8.98	9.91	0.97
Geometric mean diameter (mm)	100	9.16	9.49	0.86
Sphericity (%)	100	0.66	0.6	0.03
Surface area (mm^2)	50	101.91	120.82	8.75
Volume (cm^3)	100	350.21	422.17	31.73
Aspect ratio (%)	100	53.6	55.5	1.12

Source: Davies (2009).

moisture content, so that the static fraction coefficient increased the value of static friction coefficient for was higher that of galvanized sheet (Sahoo and Srivastava, 2002). This trend is in agreement with many researches for static coefficient of different agricultural materials on various structural surfaces (Konak et al., 2002; Ozarslan, 2002; Altuntas et al., 2005).

Firouzi et al. (2009) discovered that true density of groundnut increased from 937.7 to 1112.5 kgm^{-3} with increase of kernel moisture content from 8 to 32% db. The same trend was observed by some researchers for various seeds and kernels (Balasubramanian, 2001; Yalcin and Ozarslan, 2004; Aydin, 2007). However, they observed that the bulk density of groundnut decreased from 538.5 to 434.8 kgm^{-3} with increasing moisture content from 8 to 32% db. The decreasing trend of bulk density with increasing moisture content was also reported by Chowdhury et al. (2001), Aydin and Ozcan (2002), Abalone et al. (2004), Calibir et al. (2005a,b) and Cobkuner and Karababa (2007) for coriander seeds, grain, terebinth fruits, amaranth seeds, fenugreek rapeseed, okra seeds, pigeon pea, guna seeds and karirada seeds respectively.

According to Davies (2009), the average values for the length, width, thickness, dimensions, geometric and arithmetic mean diameter, sphericity and surface area of groundnut measured at moisture contents 7.6% dry basis (d.b.) are given in Table 2. The average magnitudes of the major, intermediate, and minor diameters for groundnut were 14.42, 9.94 and 7.57 mm respectively. Egyptian groundnut variety which have the following dimensions, length, width, thickness, geometric diameter and mass which are 12.60-24.85 mm, 5.35-11.25 mm, 4.40-10.80 mm, 7.19-13.77 mm, and 0.22-1.17 g, respectively. He also reported three varieties of groundnut pod obtained from three different countries (China, America and Egypt) showed the following range of geometric diameter 21.05, 20.59 and 20.34 mm and 2.21, 2.17 and 2.13 g of mass, respectively. The corresponding average dimension values of African nutmeg as reported by Burubai et al. (2007) for length, width and thickness were 16.6762, 11.5193 and 9.9805 mm respectively. Analysis of variance (ANOVA) revealed that the difference in physical dimensions of groundnut and African nutmeg were statistically significant at the level 0.05. The average diameter of the groundnut for arithmetic and geometric mean were 9.91 and 9.49 mm, respectively.

The mean sphericity was calculated and obtained 0.67 by Davies (2009). These values were closer to the corresponding values of 0.64 as reported for jatropha kernel (Dash et al., 2008). Davies (2009) showed that

Table 3. Gravimetric and frictional properties of groundnut at 7.6% dry basis.

Properties	Values	Standard deviation
True density (kgm^{-3})	752.34	15.57
Bulk density (kgm^{-3})	479.28	10.48
Porosity (%)	36.4	2.72
Angle of repose	28	1.2
Glass (static coefficient of friction)	0.1	0.004
Plywood (static coefficient of friction	0.13	0.003
Mild Steel (static coefficient of friction)	0.14	0.009
Concrete (static coefficient of friction	0.16	0,007

Source: Davies (2009).

there was difference in the average sphericity values 0.74 and 0.77 reported by Burubai et al. (2007), Musa and Haydar (2004) at a significant level of 0.05. The aspect ratio of groundnut was 56% and the aspect ratio of simarouba kernel was 56.41% as reported by Dash et al. (2008). This result indicated that there was no significant difference in their shapes. The ability of any grains or fruits to either roll or slide depends on the aspect ratio and sphericity.

The average 1000 grain mass of groundnut was 376 g as shown in Table 2. The corresponding reported values of simarouba kernel were 330.26 ± 29.35, jatropha 688 g, African nutmeg 897.5 g (Dash et al., 2008; Burubai et al., 2007). The average surface area of groundnut was 120.82 mm^2. The corresponding values of simarouba fruit and kernel were 687.94 mm^2 and 252.08 mm^2 respectively. A cursory look at Table 2 revealed bulk density was 479.28 ± 16.23 kgm^{-3} for groundnut while the true density was 753.34 ± 17.76 kgm^{-3}. It also revealed a significant difference ($p < 0.05$) between the average value of true and bulk density. The corresponding true and bulk density for African nutmeg were 830.54 and 488.76 kgm^{-3} as reported by Burubai et al. (2007).

The mean porosity of groundnut grain was 36.4 ± 2.1%. The static coefficient of friction for groundnut, were determined with the respect to four difference structural surfaces as shown in Table 3. It can be observed that the static coefficient of friction was highest against concrete surface 0.16 ± 0.003 followed by mild steel 0.14 ± 0.009 and plywood 0.13 ± 0.03. The least coefficient of friction was observed with glass 0.10 ± 0.002 (Davies, 2009).

Davies (2009) made the following conclusions from the study of some physical properties of groundnut seed moisture content of 7.6% dry basis. The average length, width, thickness, arithmetic and geometric mean diameter of grains were 14.21, 7.94, 7.57, 9.91 and 9.49 mm, respectively. The results obtained from his research indicated that static coefficient of friction for concrete structural surfaces were highest while glass recorded lowest. The bulk and true densities, porosity, sphericity, aspect ratio, surface area and 1000 grain mass were all investigated and reported.

CONCLUSION

Researches on physical properties of groundnut were discussed. Through this review, there have been a lot of interesting findings and insights. The principal dimensions, porosity, true density, angle of repose and static coefficient of friction were found to increase with increasing moisture content of the groundnut seeds irrespective of the variety. However, the bulk density decreased with increase in moisture content of groundnut seeds. The highest static coefficient of friction was recorded on plywood and was found to increase with increment in groundnut moisture content in all the varieties. Geometric mean diameter, sphericity and surface area increased as moisture content increased. The study of moisture dependent properties of agriculture products is of paramount importance as these guarantee an extended shelf life.

RECOMMENDATIONS

These are physical characteristics which when measured are relevant for the design and development of harvesting, seed sizing, handling, processing grading machines and in their separation from undesirable materials and decorticating and storage equipment for groundnut seeds. This information will be useful for optimizing milling operation, designing the storage structures and processing which will help to gain more relevance for the groundnut seeds among farmers and processors.

REFERENCES

Abalone R, Cassinera A, Gaston A, Lara MA (2004). Some Physical Properties of Amaranth Seeds. Biosys. Eng. 89(1):109-117.

Abioye AO, Adekunle AA, Agbasi-Ebere V (2016). Some Moisture-Dependent Physical and Thermal Properties of Bambara Groundnut. IOSR J. Environ. Sci. Toxicol. Food Technol. 10(10):65-74.

Adejumo OI, Alfa AA, Mohammed A (2005). Physical Properties of Kano White Variety of Bambara Groundnut. Proceedings of the Nigerian Institute of Agricultural Engineers held between December

12th -15th, 2005 at Yenegoa, Bayelsa State. 27:203-210.

Ajeigbe HA, Waliyar F, Echekwu CA, Ayuba K, Motagi BN, Eniayeju D, Inuwa A (2015). A Farmer's Guide to Groundnut Production in Nigeria. International Crops Research Institute for the Semi-Arid Trophies. Telangana. pp. 1-36.

Akcali ID, Lnce A, Guzel E (2006). Some Physical Properties of Peanuts. Int. J. Food Prop. 9:25-37.

Altuntas E, Ozgoz E, Yaber OF (2005). Some Properties of Fenugreek (*Trigonella foenumgraceum* L.). J. Food Eng. 71:37-43.

Anyanwu AC, Anyanwu BO, Anyanwu VA (2001). Agricultural Science for Schools and College. 6th Edn. African FEP publishers Limited, Onitsha, Nigeria, pp. 40- 41.

Aydin C, Ozcan M (2002). Some Physio-Mechanic Properties of Terebinth (*Pistacia terebinthus* L.) Fruit. J. Food Eng. 53(1):97-101.

Babic L Radojein M, Pavkov L, Babic M, Turan J, Zoramovic M, Stanisic S (2013). Physical Properties and Compression Loading Behavior of Corn Seeds. Int. Agrophys. 27:119-126.

Bagherpour H, Minae IS, Khoshtaghaza MH (2010). Selected Physio-mechanical Properties of Lentil Seeds. Int. Agrophys., 24:81-84.

Balasubramanian D (2001). Physical Properties of Raw Cashew Nut. J. Agric. Eng. Res. 78(3):291-297.

Bart-Plange A, Baryeh EA (2003). The Physical Properties of Category B Cocoa Beans. J. Food Eng. 60:219-227.

Bart-Plange A, Dzisin KA, Darko JO (2005). Effects of Moisture Content on Selected Physical Properties of Two Varieties of Cowpea. Agric. Food Sci. J. Ghana 4:329-340.

Baryeh AE, Mangope BK (2002). Some Physical Properties of Qp–38 Variety of Pigeon Pea. J. Food Eng. 56(1):59-65.

Burubai W, Akor AJ, Igoni AH, Puyate YT (2007). Some Physical Properties of Nutmeg. Int. Agrophys. 21:123-126.

Burubai W, Amber B (2014). Some Physical Properties and Proximate Composition of Ngologolo Fruits. J. Food Process Technol. 6(5):331.

Calibir S, Marakoglu T, Ogut H, Ozturk O (2005) Physical Properties of Rapeseed (*Brassica napusoleifera* L.). J. Food Eng. 69:61-66.

Calibir S, Ozcan M, Hactseferogllaric H, Yildiz MU (2005b). A Study on Some Physiochemical Properties of Turkey Okra (*Hibiscus esculenta* L.) Seeds. J. Food Eng. 68:73-78.

Chowdhury MMI, Sarker RI, Bala BK, Hossain MA (2001). Physical Properties of Gram as a Function of Moisture Content. Int. J. Food Prop. 4 (2):297-310.

Cobkuner Y, Karababa E (2007). Some Physical Properties of Coriander Seeds (*Coriandruim sativum* L). Journal of Food Eng. 89:408-416.

Correa PC, Schwanz da Silva F, Jaren C, Afonso Junior PC, Arana I (2007). Physical and Mechanical Properties in Rice Processing. J. Food Eng. 79:137-142.

Coskun MS, Yalcini I, Ozarslan C (2006). Physical Properties of Sweet Corn (*Zea mays saccharata* Sturt). J. Food Eng. 74:523-528.

Dash AK, Pradhan RC, Das IM, Naik SN (2008). Some Physical Properties of Simabouba Fruit and Kernel. Int. Agrophys. 22:111-116.

Davies RM (2009). Some Physical properties of Groundnut Grains. Res. J. Appl. Sci., Eng. and Technol. 1(2):10-13.

Davies RM, El-Okon AM (2009). Moisture-Dependent Physical Properties of Soybeans. Int. Agrophys. 29:299-303.

Davies RM (2010). Some Physical Properties of Arigo Seeds. Int. Agrophys. 24:89-92.

De Figueiredo AK, Baumber E, Riccobene IC and Nolasco SM (2011). Moisture-Dependent Engineering Properties of Sunflower Seeds with Different Structural Characteristics. J. Food Eng.102:58-65.

FAOSTAT (2014). Available at http://www.faostat.fao.org

Fellow PJ (2000). Food Processing Technology: Principles and Practice. 2nd Edn. CRC Press, Boca Raton, Florida.

Figura LO, Teixeira AA (2007). Physical Properties Measurement and Application. Food Physics. Springer, Berlin.

Firouzi S, Mishgaci MNS, Kaviani B (2009). Some Physical Properties of Groundnut (*Arachis hypogaea* L.) Kernel cv. NC2 as a Function of Moisture Content. American- Eur. J. Agric. Environ. Sci. 6(6):675-679.

Galedar MN, Jafari A, Tabatabaeefa A (2008). Some Physical Properties of Wild Pistachio nut and Kernel as a Function of Moisture Content. J. Phys. Environ Agric. Sci. 22:117-124.

Gharibzahedi SMT, Eterned V, Mirarab-Razi J, Foshat M (2010). Study on Some Engineering Attributes of Pine Nut (*Pinus pinea*) to the Design of Processing Equipment. Res. Agric. Eng. 56(3):99-106.

Ixtaina VY, Nolasco SM, Tomas MC (2008). Physical Properties of Chia (*Salvia hispanica* L.) Seed. Ind. Crops Prod. 28:286-293.

Kaleemullah S, Gunasekar JJ (2002). Moisture Dependent Physical Properties of Arecanut Kernels. Biosys. Eng. 52:331-338.

Karababa E (2006). Physical Properties of Popcorn Kernel. J. Food Eng. 72:100-107.

Konak MK, Carman K, Aydin C (2002). Physical Properties of Chick Pea Seeds. Biosys. Eng. 82(1):73-78.

Koocheki A, Razavi SMA, Milani E, Moghadan TM, Abedini M, Alamatiyan S, Izadikhah S (2007). Physical Properties of Watermelon Seed as a Function of Moisture Content and Variety. Int. Agrophys. 21:349-359.

Manuwa SI, Afuye GG (2004). Moisture Dependent Physical Properties of Soya bean (Var-TGx 1871-5E). Nigeria J. Ind. and Studies 3(2):45-54.

Milani E, Razavi SMA, Koocheki A, Nikzadeh V, Ahedi NV, Moeinford M, Gholamhosseinpour A (2007). Moisture Dependent Physical Properties of Cucurbit Seeds. Int. Agrophys. 21:157-168.

Muhammad AI, Ahmad RK, Lawan I (2017). Effect of Moisture Content on Some Engineering Properties of Groundnut Pods and Kernels. Agric. Eng. Int. CIGR J. 19(4):200-208.

Musa O, Haydar H (2004). A condiment (*Sumec Rhus coriaria* L); Some Physico-Chemical Properties. Bulg. J. Plant Physiol. 30(3):74-84.

Nalladulai K, Alagusundaram K, Gayathri P (2002). Airflow Resistance of Paddy and Its By-products. Biosys. Eng. 831 (4):67-75.

Nesvadha P (2005). Thermal Properties of Unfrozen Foods. In: Rao, M. A.; Rizvi, S. S. H. and Datta, A. K. (Eds). Engineering Properties of Foods. 3rd Edn. CRC Press New York pp. 149-173.

Odesanya KO, Adebiyi KA, Salau TAO (2015). Estimation of Engineering Parameters for the Development of a Groundnut Decorticator. Int. J. Novel Res. Eng. Appl. Sci. 2(1):2-25.

Ogunjimi LAO, Aviara NA, Aregbesola OA (2002). Some Physical Engineering Properties of Locust Bean Seed. J. Food Eng. 55:95-99.

Olaoye JO (2000). Some Physical Properties of Castor Nut Relevant to the Design of Processing Equipment. J. Agric. Eng. Res. 77(1):113-118.

Opeke LK (2006). Essential of Crop Farming. Spectrum Book Limited. Spectrum house Ring Road, Ibadan, pp. 81-84.

Ozarslan C (2002). Physical Properties of Cotton Seeds. Biosys. Eng. 53(1):97-101.

Razari MA, Emadzadeh B, Rafe A, Mohammed AA (2007). The Physical Properties of Pistachio Nut and its Kernel as a Function of Moisture Content and Variety, Part 1: Geometric Properties. J. Food Eng. 81:209-217.

Reddy BS, Chakraverty A (2004). Physical Properties of Raw and Parboiled Paddy. Biosys. Eng. 88(4):461-466.

Sacilik K, Ozturk R, Keskin (2003). Some Physical Properties of Hemp Seeds. Biosys. Eng. 86(2):191-198.

Sahoo PK, Srivastava AP (2002). Physical Properties of Okra Seed. Biosys. Eng. 83(4):441-448.

Singh G (2009). Plant Systematics, Theory and Practice, 2nd Edition. Oxford and IBH Publishing Co. Pvt. Limited, New Delhi, pp. 398-407.

Singh KK, Mridula D, Bamuwal P, Rehal J (2012). Physical and Chemical Properties of Flax Seeds. Int. Agrophys. 26:423-426.

Tabatabaeefa A (2003). Moisture-Dependent Physical Properties of Wheat. Int. Agrophys. 12:207-211.

Varnamkhasti MG, Mobli H, Jafari A, Keyhani AR, Soltanabadi MH, Rafice S, Kheiralipour K (2008). Some Physical Properties of Rough Rice (*Oryza Sativa* L.) Grains. J. Cereal Sci. 47(3):496-501.

Yalcin I, Ozarslan C (2004). Physical Properties of Vetch Seed. Biosys. Eng. 89(4):507-512.

Zare D, Bakhshipour A, Chen A (2013). Physical Properties of Cumin and Caraway Seeds. Int. Agrophys. 27:491- 494.

Zhao X, Chen J, Du F (2012). Potential Use of Peanut By-Product in Food Processing: A Review. J. Food Sci. Technol. 49(5):521-529.