Vol. 14(10) pp. 353-365, November 2020
DOI: 10.5897/AJFS2020.1974
Article Number: B8E6C2465215
ISSN: 1996-0794

http://www.academicjournals.org/AJFS

ACADEMIC JOURNALS
expand your knowledge

African Journal of Food Science

Full Length Research Paper

Physical properties of selected groundnut (*Arachis hypogea* L.) varieties and its implication to mechanical handling and processing

Hayford Ofori[1]*, Francis Amoah[1], Isaac Kojo Arah[2], Mohammed-Kamil Abukari Piegu[3], Isaac Albert Aidoo[1] and Eric Donald Nii Akpen Commey[1,4]

[1]Department of Agricultural Engineering, Ho Technical University, Ho, Ghana.
[2]Department of Agro Enterprise Development, Ho Technical University, Ho, Ghana.
[3]Department of Agricultural Engineering, Tamale Technical University, Tamale, Ghana.
[4]Agricultural Engineering Services Directorate, Ministry of Food and Agriculture, Accra, Ghana.

Received 28 May, 2020; Accepted 15 October, 2020

The physical properties of agricultural materials are functional in solving many glitches associated with machine design during handling and mechanical processing. Physical properties of five groundnut varieties ("*Obolo*", "*Yenyawoso*", "CRI *Nkatie*", "*Agbeyeyie*" and "*Pion*") and their relations to the design of food processing equipment were studied. *Obolo* variety recorded the maximum axial dimensions, 1000 mass grain, angle of repose, unit volume, and porosity. However, the values of bulk and true densities for *Obolo* variety were minimal compared with the other four varieties. Data for the angle of repose for the groundnut varieties were 17.74° (*Yenyawoso*), 18.02° (*Pion*), 18.73° (*Agbeyeyie*), 18.71° (*Cri-Nkatie*), and 18.89° (*Obolo*). The porosity of the kernels ranged from 21.97 to 24.54%. The mean greatest porosity was found in *Obolo* (24.54%), followed by *Yenyawoso* (24.38%), while *Agbeyeyie* recorded the least mean porosity of 21.97%. The coefficient of friction was greater for the galvanized steel surface than the other experimental surfaces for all the groundnut varieties studied. Analysis of variance (ANOVA) revealed varietal differences among some means of the physical attributes at $p < 0.05$. Except for the angle of repose, the geometric, gravimetric and frictional properties showed some significant differences at $p < 0.05$. *Obolo* variety was statistically different compared with the other four varieties for all the parameters studied. In selecting or designing equipment for processing, *Obolo* variety will require separate equipment different from that of the other four varieties. Additionally, the study provides pertinent data for use in the selection and designing of machines for processing groundnut kernels.

Key words: Postharvest processing equipment, geometric mean diameter, bulk density, frictional properties, groundnut kernels, angle of repose.

INTRODUCTION

The rate of population growth in the world coupled with demand for quality and safety of food materials require appropriate postharvest machineries for handling, processing, preservation and storage. An empirical data on engineering properties of agricultural biological materials will provide a suitable basis for designing and selection of the right equipment for the various postharvest operations to ensure that the processed biological material is of quality and safe for consumption. Data on engineering properties such as thermal, physical, mechanical, sensory, frictional, electromagnetic and aerodynamic properties, among others are vital for designing and selection of equipment for mechanical handling and processing of any agricultural biological materials. Among these properties, physical properties of biological materials are of great significance (Ofori et al.., 2019).

The knowledge in physical property provides a basis for better option during designing and selection of appropriate equipment for mechanical handling and processing of agricultural products. A determining factor for selection and designing of equipment for processing is linked-up with the physical attributes of the product. Among these attributes include, 1000 grain mass, axial size, volume, mass per unit volume, porosity, angle of repose, and the frictional properties. The importance of these physical attributes are valuable in choosing sieve separators, aeration, heating, estimating cooling, determining power requirement during size reduction process, displaying of grain drying, and scale draw of preharvest and postharvest equipment (Khan et al., 2019). The use of equipment for sorting, grading, cleaning and processing into different items all require data on the physical attributes of the biological materials (Stroshine and Hamann, 1995). Equipment and operating variable for size reduction, receptacle containers, grain silos, grain hopper dimensions, and holding facilities all depends on the engineering properties of biological materials of which physical attributes form great significance (Khan et al., 2019; Serpil and Servet, 2006).

Experiential knowledge on data abounds with physical properties of biological materials for bambara groundnut (Baryeh, 2001), tiger nut (Abano and Amoah, 2011), *Moringa oleifera* seeds (Aviara et al., 2013) and inter alia. Physical properties of several other local varieties of groundnut pods and kernel have been examined in different countries (Krishnappa et al., 2017; Firouzi et al., 2009; Olajide and Igbeka, 2003; Akcali et al., 2006). Data on anatomical structure of grain is critical for conducting movement of heat during processes such as drying, cooling, freezing and thawing. The rate of drying of biological materials is dependent on the nature of the exposed surface as well as the volume of the material; the more exposed of the surface and lesser volume, the quicker the rate of dispersion of water from the material. Density, size and shape of biological materials are product determinants for estimating terminal velocity in from product with different varieties. Equipment design for processing will be affected if consideration to the physical properties is compromised (Bala, 2017). Safety and quality of processed material is paramount to consumers, hence, appropriate design of equipment for processing are key. Designing of efficient processing equipment significantly depends on the kernel physical properties. Frequent equipment reinvention without consideration to empirical data of the biological material in question contributes to environmental pollution which affects the climate. The operational effectiveness and output to input ratio of processing equipment such as seed cleaners, grading, sorting, conveyors, and seed metering mechanism systems are dependent on the physical attributes of the biological material, and the data on these properties must be carried out and characterized appropriately.

With groundnut production and consumption cutting across all the sixteen regions of Ghana, empirical data on the kernels are momentous in selecting or designing machine for processing and storage. The need to investigate these common elite varieties of groundnut kernels recently released by the Crop Research Institute (CRI), Fumesua, Ghana, to assist in making well informed choices cannot be overemphasized. This research offers appropriate data on geometric, gravimetric and frictional properties of the selected groundnut varieties as a basis for designing and selection of equipment for processing and storage. This study therefore, seeks to determine the geometric, gravimetric and frictional attributes of these groundnut varieties and their correlation to the designing of mechanical equipment for food handling, processing and storage.

MATERIALS AND METHODS

Five groundnut varieties namely: "*Obolo*", "*Yenyawoso*", "CRI *Nkatie*", "*Agbeyeyie"* and "*Pion*" (Figures 1 to 5) used for the study were obtained from the warehouse of Crop Research Institute (CRI), under the Council for Scientific and Industrial Research (CSIR) at Fumesua, Ghana. These samples were manually cleaned free from dirt, leaves, pest and weeds. A sample size of 2 kg each was used for the analysis. The storage moisture contents (MC) of the groundnut kernels when measured were 7.2, 7.9, 7.8, 7.9 and 7.8% wet basis (wb), respectively, for "*Obolo*", "*Yenyawoso*", "CRI *Nkatie*", "*Agbeyeyie"* and "*Pion*". The initial MC of the kernels was obtained by using the method essayed by Ofori et al. (2019) as in Equation 1.

$$\% MC_{wb} = \frac{M_r}{M_i} \times 100 \quad (1)$$

where MC_{wb} = percentage moisture content in wet basis, M_r = mass of water removed and M_i = initial mass of sample before drying.

*Corresponding author. E-mail: hofori@htu.edu.gh.

Figure 1. Sample of the *Obolo* (ICGV 97049) variety.

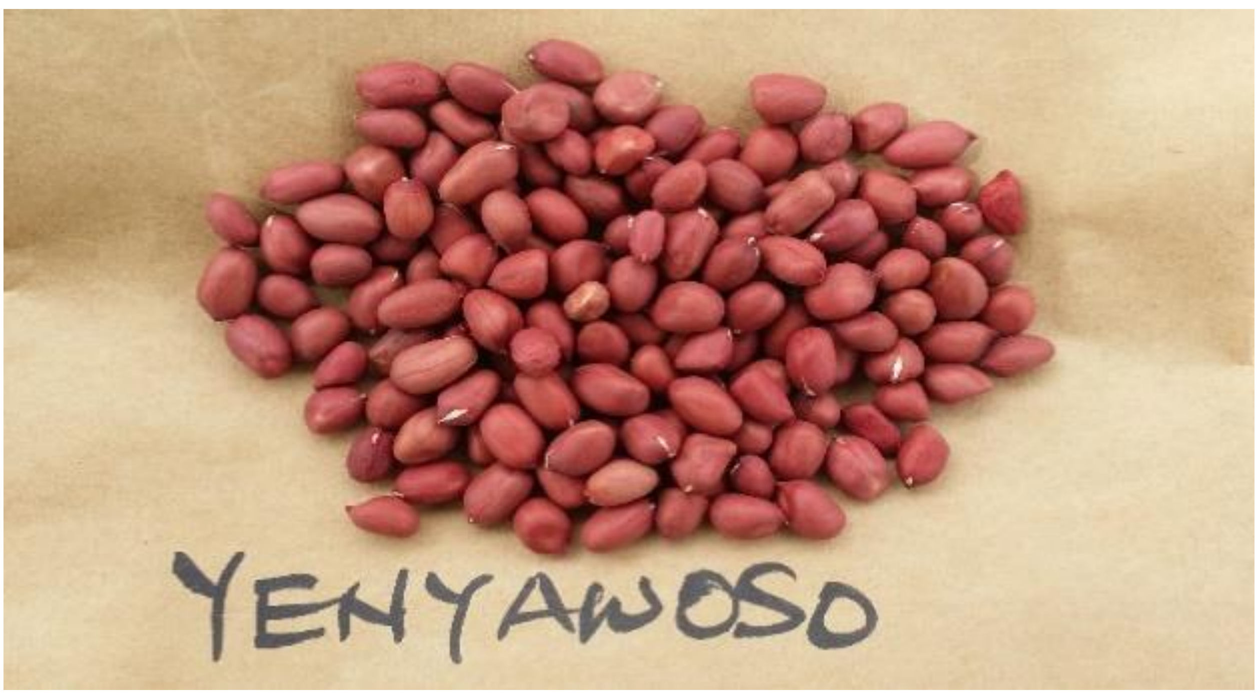

Figure 2. Sample of the Yenyawoso (ICGX SM 87057) variety.

A sample size of one hundred kernels were stochastically chosen from the 2 kg mass sample and the principal axial dimensions of the kernels were determined (Figure 6). From each sample size, three axial dominant dimensions, that is length (L), width (W) and thickness (T) were determined with a digital vernier caliper of precision of ±0.01 mm (Aviara et al., 2013). The geometric parameters [Arithmetic mean diameter (D_a), geometric mean diameter (D_g), sphericity (∅), surface area (S) and aspect ratio (R)]

Figure 3. Sample of the CRI-Nkatie variety.

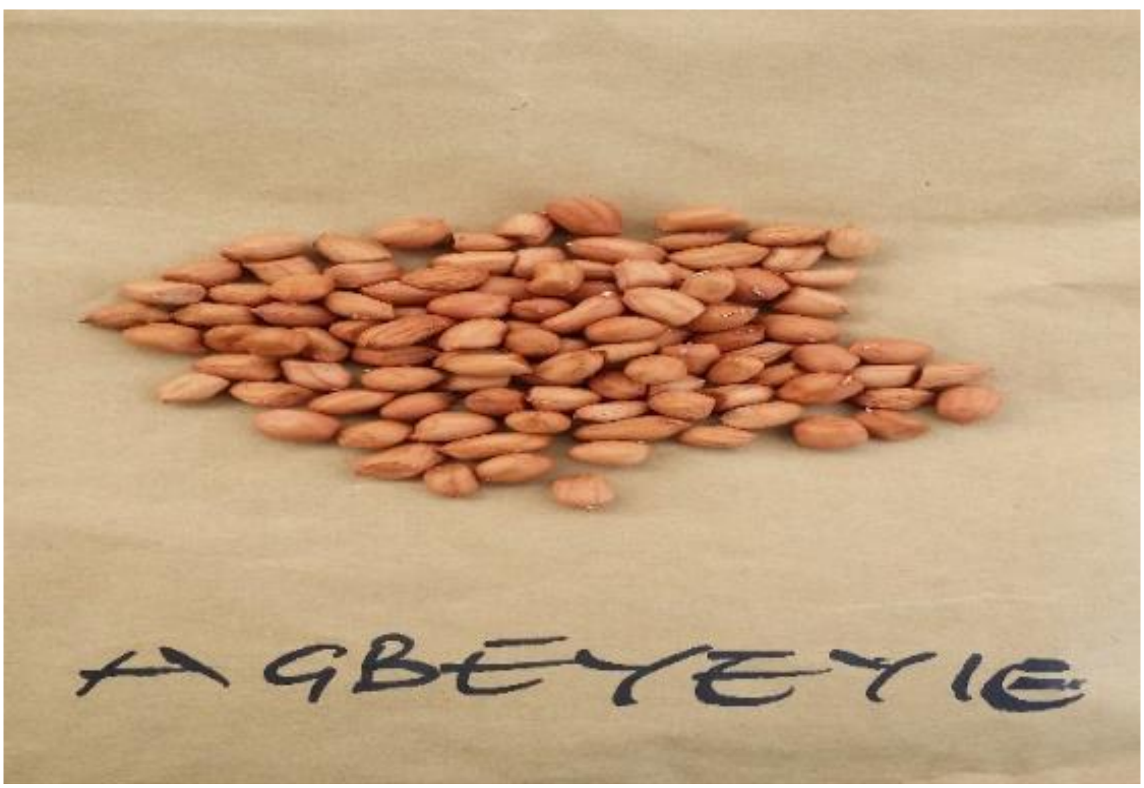

Figure 4. Sample of the CRI-Agbeyeyie variety.

were then estimated from the sample measured axial dimensions.

Equations 2, 3 and 4 were used respectively, to determine arithmetic mean diameter (D_{am}), geometric mean diameter (D_{gm}) and sphericity (Ø) (Aviara et al., 2013; Khan et al., 2019; Mohsenin,

Figure 5. Sample of the CRI-Pion variety.

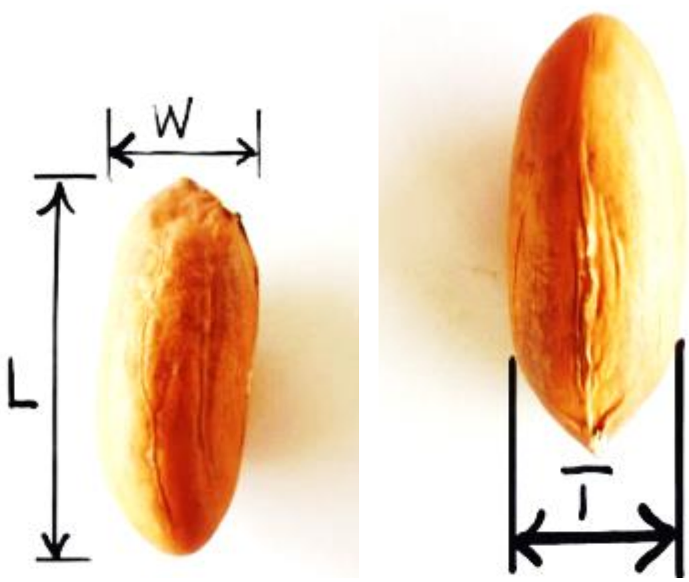

Figure 6. Principal dimensions of groundnut kernel.

1986; Vengaiah et al., 2015).

$$D_{am} = \frac{(L + W + T)}{}, mm \quad (2)$$

$$D_{g_m} = (LxWxT)^{1/3}, mm \quad (3)$$

$$Ø = \frac{(LxWxT)^{1/3}}{L} x100\% \quad (4)$$

Equations 5 and 6 were used to obtain for the surface area (S) and aspect ratio (R) of the kernels, respectively.

$$S = \pi (D_g)^2, mm^2 \quad (5)$$

$$R = \frac{W}{L} \quad (6)$$

Mathematical Equation 7, ascribed to Jibril et al. (2016) was used to compute for the unit volume (V) of 100 individual kernels.

$$V = \frac{\pi LWT}{6} \quad (7)$$

A mass of 100 randomly sampled kernels was measured using a digital balance of precision 0.001 g. To obtain the thousand (1000) grain mass (TGM) of the groundnut kernels, the measured mass of the 100 kernels was multiplied by 10 (Aviara et al., 2013).

The method described by AOAC (1980), was used to estimate the bulk density. A cylinder of known volume 500 ml was filled with groundnut kernels from a height of 15 cm, the additional kernels were taken-off using a flat rule carefully to prevent compaction. Quantity of kernels that filled the cylinder was weighed with a digital balance. Bulk density was computed for using Equation 8.

$$\rho_b = \frac{m_b}{v_b} \quad (8)$$

where ρ_b = Bulk density (g/cm^3), m_b = Mass of the kernel sample (g) and v_b = Volume of sampler (cm^3)

The particle (true) density was determined using Equation 9 as reported by Khan et al. (2019) and Vengaiah et al. (2015). A quantity of known mass of seeds were poured into a measured volume of toluene (C_7H_8) as liquid for displacement in a graduated cylinder, and the true density of the seed found as the ratio of the mass of sample of seeds to the solid volume occupied by the sample.

$$\rho_t = \frac{mass(g)}{v_2 - v_1(cm^3)} \quad (9)$$

where ρ_t = true density, g/cm^3; v_1 = initial volume of toluene, cm^3; and v_2 = final volume of toluene, cm^3.

The method described by Mohsenin (1986) as in Muhammad et al. (2015) in Equation 10 was used to compute for the porosity (ε) of the bulk kernel.

$$\varepsilon = \frac{\rho_t - \rho_b}{\rho_t} \times 100\% \quad (10)$$

A method reported by Serpil and Servet (2006) was employed to obtain the angle of repose. A circular plate of known diameter was placed under an open-ended cylinder of size 150 mm in diameter and 220 mm in height. Grain samples were poured into the cylinder from a pre-determined height until it was full. The cylinder was carefully raised for kernels to form a cone on the circular plate. The angle of repose was calculated by the ratio of the height to the base radius of the heap formed.

The coefficient of static friction (μ) was assayed with three different structural surfaces, viz, glass, polished wood and galvanized steel. To measure the static friction, an open-ended PVC cylinder 110 mm in diameter and 90 mm in height was stuffed with kernel and placed on an inclined plane. The PVC cylinder was elevated about 2.5 mm off-contact from the slanted board. The slanting board was lifted bit by bit with the aid of an adjustable mechanism until the cylinder began to move. The angle of tilt was measured with a protractor. Measurement was repeated three times and for each repeat, the sample in the container was poured out and refilled with a fresh sample. Equation 11 was used to calculate for the static coefficient of friction (Vengaiah et al., 2015).

$$\mu = \tan \theta \quad (11)$$

where μ is the coefficient of static friction and θ is the angle of tilt of table.

Data analysis

Analysis of variance (ANOVA) was performed on the data of the physical attributes measured and computed using SPC for Excel v5 (trial) hosted on Microsoft Excel 2016 at 5% significance level. A trial of least significance difference (LSD) was performed on the means of the physical attributes measured for the five varieties of the groundnut kernels.

RESULTS AND DISCUSSION

Results of the principal dimensions for the five groundnut kernels are depicted in Table 1. Figures 7 to 11 depict the variations of the kernel three axial magnitudes (length, width and thickness). The degree of variations in the minimum and maximum widths and thicknesses among the kernels studied were minimal as shown in Figures 7 to 11. However, differences among kernels minimum and maximum lengths were clearly evident, of which the highest value was found in *Obolo* variety (8 mm), followed by *Agbeyeyie* (7.5 mm) and the lowest was recorded in *Yenyawoso* and *pion* at 4.5 mm each. Grading to obtain uniform sizes is imperative for planting with the use of a metering mechanism. *Obolo* variety had the highest minimal and maximal range of sizes 15.00 to 23.00 mm, 7.47 to 11.67 mm and 8.90 to 11.95 mm, respectively, for the length, width and thickness. The lowest minimal and maximal range of sizes for length, width and thickness were registered for *Yenyawoso* variety which were, respectively at 9.37 to 15.42 mm, 6.16 to 9.27 mm and 6.14 to 10.11 mm. These seed dimensions are useful for selection or designing sieve apertures in the segregation compartment of machine for shelling (Maduako and Hamann, 2005). The obtained data in Table 1 shows that among the five groundnut varieties studied, *Obolo* variety recorded the largest sizes in terms of length, width and thickness. However, the remaining four varieties were ostensibly similar in axial dimensions. Empirical data on axial dimensions of any biological material is imperative with the reason that equipment for processing of these bio-materials is dependent on the physical attributes (Davies, 2010).

Table 1. Geometric parameters of selected physical properties.

Geometric parameter	Number of observations	Variety				
		Obolo	Yenyawoso	CRI Nkatie	Agbeyeyie	Pion
Moisture Contents (%, wb)		7.2	7.9	7.8	7.8	7.8
Length (mm)	100	18.92 (1.63)	12.35 (1.09)	13.64 (1.11)	12.44 (1.16)	12.62 (0.96)
Width (mm)	100	9.63 (0.84)	7.82 (0.51)	7.79 (0.57)	8.11 (0.66)	7.99 (0.57)
Thickness (mm)	100	10.23 (0.65)	8.24 (0.69)	8.40 (0.56)	8.59 (0.59)	8.54 (0.54)
Arithmetic diameter (mm)	100	12.92 (0.69)	9.47 (0.48)	9.94 (0.56)	9.71 (0.53)	9.71 (0.47)
Geometric diameter (mm)	100	12.28 (0.61)	9.25 (0.46)	9.62 (0.53)	9.52 (0.51)	9.50 (0.45)
Sphericity (%)	100	65.21 (4.34)	75.26 (5.38)	70.79 (4.31)	76.93 (5.67)	75.55 (4.57)
Surface area (mm^2)	100	474.98 (46.74)	269.31 (26.78)	291.50 (32.65)	285.43 (30.57)	284.13 (26.98)
Aspect ratio (%)	100	0.51 (0.07)	0.64 (0.07)	0.57 (0.06)	0.66 (0.08)	0.64 (0.07)

Values for standard deviation depicted in parenthesis.

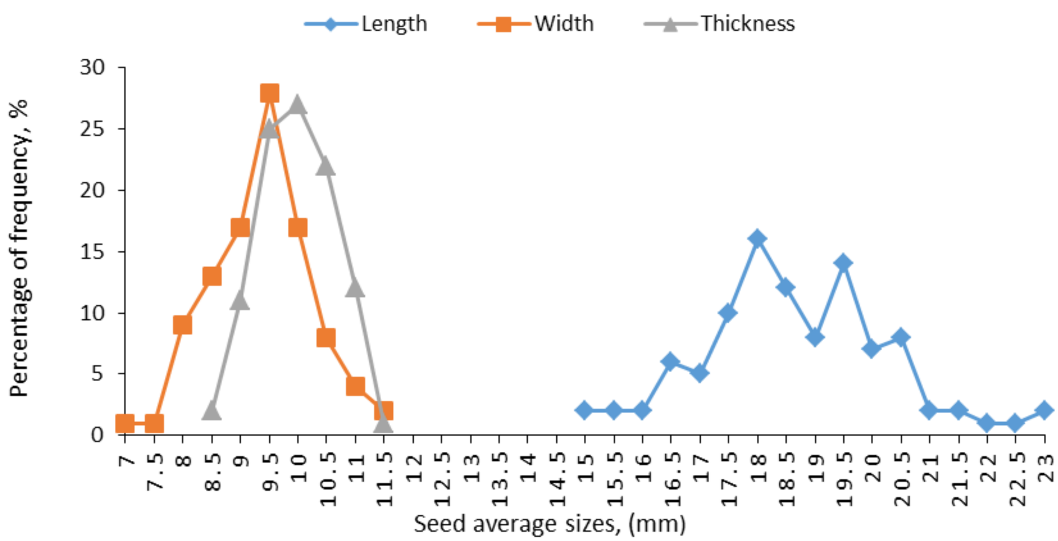

Figure 7. Frequency distribution curves of ICGV 97049 (*Obolo*) seed dimensions.

Hence, in designing sieves for cleaning, *Obolo* variety will have different sieve-size due to its immense axial dimensions distinct from that of the other four varieties.

Geometric and arithmetic mean diameters

The geometric and arithmetic mean diameters for the kernels had averages of 12.28 and 12.92 mm, 9.25 and 9.47 mm, 9.62 and 9.94 mm, 9.52 and 9.71 mm, and 9.50 and 9.71 mm, respectively, for the *Obolo, Yenyawoso, CRI-Nkatie, Agbeyeyie* and *Pion* varieties as presented in Table 1. Geometric mean diameters and the arithmetic mean diameters for the varieties studied are in variance with those of Manipintar, Local I and Local II (Muhammad et al., 2015) as well as RMP-9, ICGV and RMP-12 groundnut varieties (Vengaiah et al., 2015). This variation may be due to varietal differences. Having the requisite data on these properties is significant in the determination of the clearance within the concave openings of groundnut decorticating and separating machines. Also, these attributes are important in screening out solids to remove foreign materials as well as designing equipment for grading.

Sphericity

Sphericity depicts the shape of a biological material in variance to sphere. The mean values of sphericity were 65.21% (*Obolo),* 75.26% (*Yenyawoso),* 70.79% (*CRI-Nkatie),* 76.93% (*Agbeyeyie)* and 75.55% (*Pion)* for the kernels as presented in Table 1. *Agbeyeyie* variety had the highest mean sphericity while the least mean

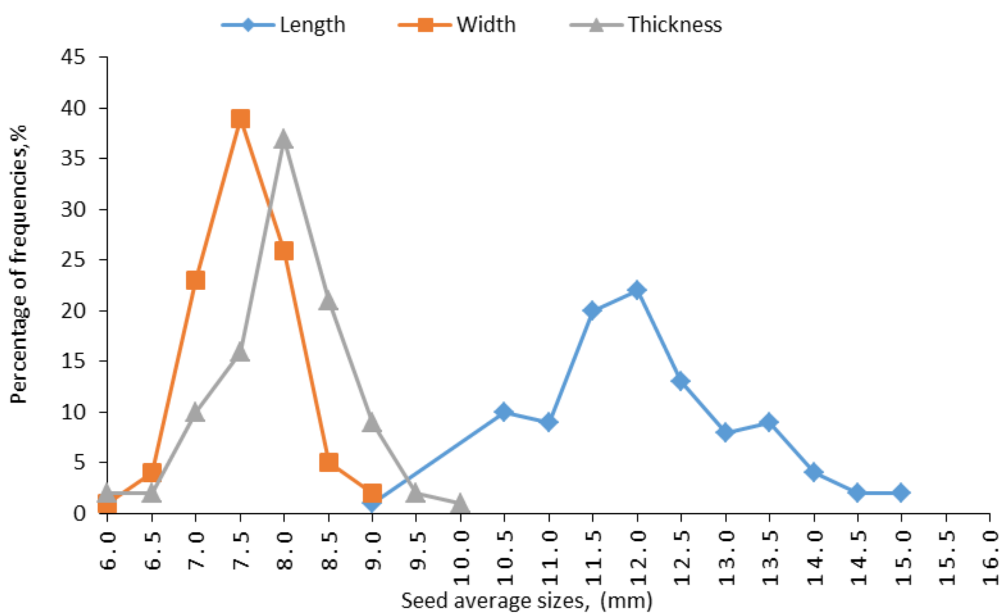

Figure 8. Frequency distribution curves of ICGX SM 87057 (*Yenyawoso*) seed dimensions.

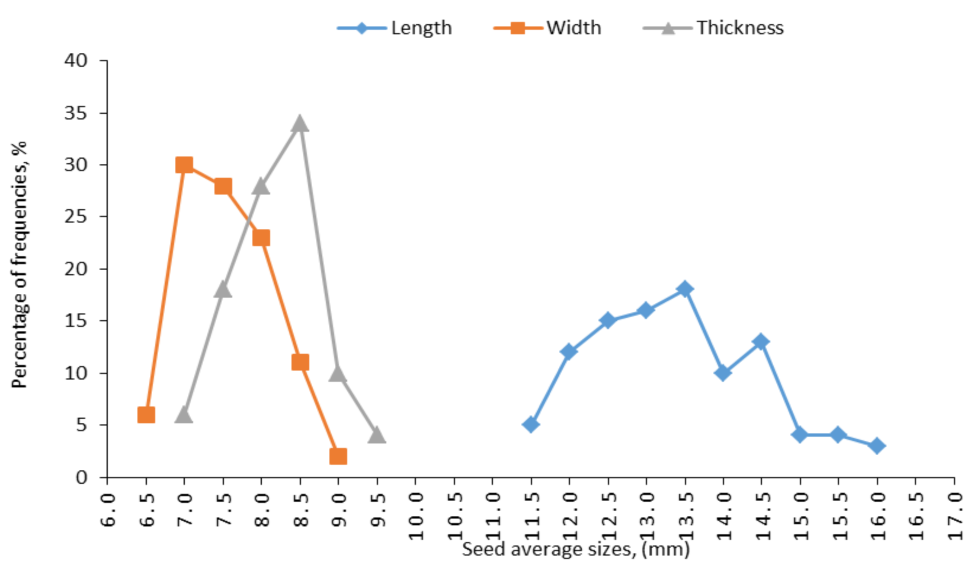

Figure 9. Frequency distribution curves of (CRI-Nkatie) seed dimensions.

sphericity was found in *Obolo*. A sphericity value of a biomaterial between 50 and 100% is an indication of the ability of that material to slide on the surface in contact with it (Muhammad et al., 2015). These values obtained for sphericity indicate that all the groundnut kernels have the propensity to roll on its axis. A spiral separator cleaner can be used for cleaning and removal of immature and shrivelled kernels due to the rolling ability of the kernels. A similar trend was found by Muhammed et al. (2015) for Local II and Manipintar with sphericity of 64.20 and 78.24%, respectively.

Surface area

Surface area is vital for quantifying the rate of heat, water and gas transfer during processing such as drying and roasting of kernels. The larger the surface area of the material, the higher the exposure of kernel to the heat source and the greater the heat absorption and

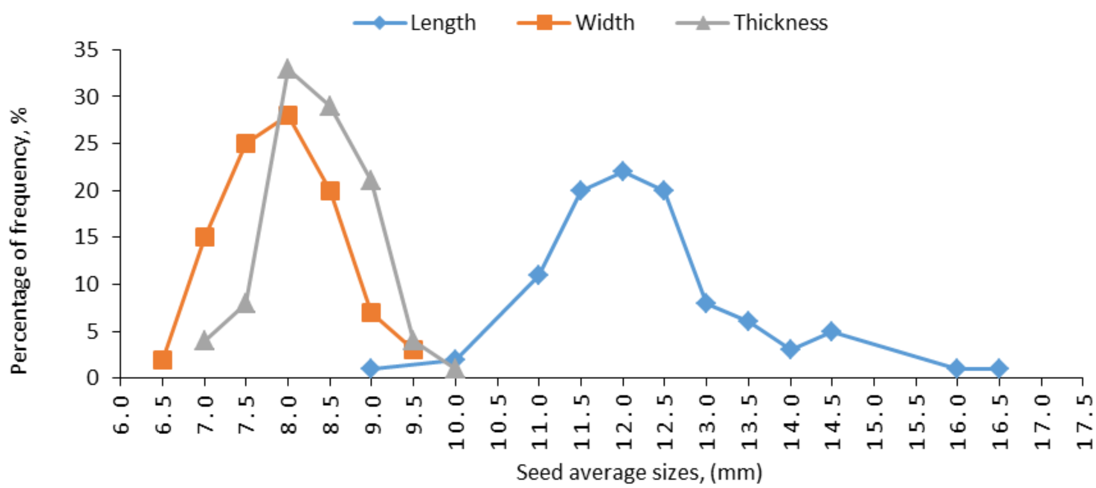

Figure 10. Frequency distribution curves of (CRI Agbeyeyie) seed dimensions.

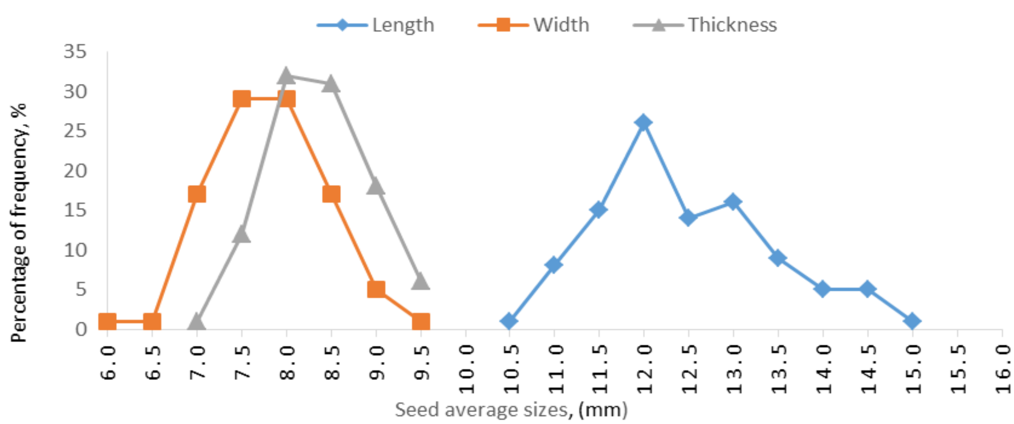

Figure 11. Frequency distribution curves of (CRI Pion) seed dimensions.

desorption during processing that involves heating (drying or roasting) and cooling of kernels (Bala, 2017). From Table 1, the surface areas of the kernels were 269.31, 284.13, 285.43, 291.50 and 474.98 mm^2 for *Yenyawoso, Pion, Agbeyeyie, Cri-Nkatie* and *Obolo,* respectively*.* Odesanya et al. (2015) found surface areas of 149 and 97 mm^2, espectively, for Samnut 22 and Ex-Dakar. This variation may be due to varietal differences in the products investigated.

Thousand (1000) seed mass

The mean values for the 1000 grain mass of the groundnut kernels were 843.70, 416.66, 420.30, 429.30 and 452.10 g for *Obolo, Yenyawoso, Cri-Nkatie, Agbeyeyie* and *Pion*, respectively (Table 2). Among the five varieties, *Obolo* had the highest mean of thousand grain mass of 843.70 g while *Yenyawoso* had the least value of 416.66 g. The thousand grain mass is substantial in calculating the size of grain holder units (hoppers) and shelling compartments of machines for processing. The 1000 grain mass property is also useful for estimating machine stability during operations such as size reduction and planting (Muhammad et al., 2015).

True and bulk densities

The minimum bulk density of the groundnut kernels was found in *Obolo* variety (758.05 kg/m^3) and the maximum was found in *Agbeyeyie* variety (799.71 kg/m^3). Also, *Obolo* variety recorded the minimum true density of 1004.43 kg/m^3 while the maximum was recorded in Pion variety (1033.67 kg/m^3) as shown in Table 2. The results obtained attest to that recorded by Muhammad et al. (2015) for bulk density range of 0.55 to 0.82 g/cm^3 and true density from 0.87 to 1.08 g/cm^3 for Local II and

Table 2. Gravimetric parameters of selected physical properties.

Gravimetric parameter	Number of observations	Variety				
		Obolo	Yenyawoso	CRI Nkatie	Agbeyeyie	Pion
Moisture contents (%, wb)		7.2	7.9	7.8	7.8	7.8
Unit volume (mm^3)	3	976.82 143.77)	417.07 (62.07)	470.12 (79.93)	455.34 (73.52)	451.83 (64.32)
1000 Grain mass (g)	3	843.70 (0.10)	416.66 (1.15)	420.30 (0.26)	429.30 (0.10)	452.10 (0.10)
Bulk density (kg/m^3)	3	758.05 (1.51)	797.77 (11.04)	792.77 (8.05)	799.71 (4.22)	792.79 (2.03)
True density (kg/m^3)	3	1004.43 (1.37)	1029.98 (2.60)	1020.733 (5.04)	1024.33 (0.67)	1033.67 (2.31)
Porosity (%)	3	24.53 (0.11)	22.48 (1.44)	22.34 (0.13)	21.96 (0.41)	23.43 (0.14)

Values for standard deviation depicted in parenthesis.

Table 3. Frictional parameters of selected physical properties.

Frictional parameter	Number of observations	Variety				
		Obolo	Yenyawoso	CRI Nkatie	Agbeyeyie	Pion
Moisture contents (%, wb)		7.2	7.9	7.8	7.8	7.8
Angle of repose(deg.)	3	18.89 (0.69)	17.74 (0.45)	18.71 (0.23)	18.73 (0.44)	18.02 (0.63)
Coefficient of friction						
Glass	3	0.39 (0.019)	0.32 (0.015)	0.32 (0.015)	0.32 (0.012)	0.32 (0.008)
Galvanized steel	3	0.46 (0.008)	0.34 (0.010)	0.33 (0.012)	0.35 (0.010)	0.34 (0.012)
Polished wood	3	0.42 (0.021)	0.34 (0.006)	0.32 (0.014)	0.33 (0.010)	0.33 (0.010)

Values for standard deviation depicted in parenthesis.

Manipintar, respectively. It also concurs with that found by Maduako and Hamman (2005). These properties are useful tools for evaluating maximum load that seed separators can resist without breaking down during groundnut shelling. The particle and the bulk densities are valuable for estimating the aero and hydrodynamic separation of groundnut kernels from foreign material and imposed pressures during design of silo bottoms.

Porosity

Table 2 depicts the porosity of the groundnut kernels. This attribute provides significant information when developing equipment for material handling such as drying, storage, aeration and ventilation. It is also a useful determinant property for estimating material transport in pneumatic conveyors. The porosity for the five kernel varieties ranged from 21.97 to 24.54%. *Obolo* variety recorded the highest mean porosity of 24.54%, followed by *Yenyawoso* with 24.38%. *Agbeyeyie* recorded the least mean porosity of 21.97%. The experimental data obtained concurs with that obtained by (Firouzi et al., 2009) for Local I, Manipintar and Local II with porosities of 24.70, 28.89 and 37.00%, respectively. Boukouvalas et al. (2006) indicated that porosity is among the single most significant properties by which the shape of food materials can be described. Porosity is a critical parameter among others for equipment design.

Angle of repose

Data obtained for the angle of repose were 17.74° (*Yenyawoso*), 18.02° (*Pion*), 18.73° (*Agbeyeyie*), 18.71° (*Cri-Nkatie*) and 18.89° (*Obolo*) as in Table 3. These values are closely related to that of Maduako and Hamman (2005), who obtained 20.03° for ICGV-SM-93523, 20.05° for RMP-9 and 20.8° for RMP-12 groundnut seeds, but lower than that obtained by Muhammad et al. (2017). As depicted in Table 3, the angle of repose for kernels of smaller axial dimensions was less than that for bigger seeds. The study unraveled that smaller seeds have smaller and smoother surface area as compared to larger seeds which have larger and rougher surface area, hence flowability is reduced with decreasing angle. This property is valuable for determination of optimum sides for planting machine seed hoppers, silos and storage containers to allow easy sliding of materials (El-Fawal et al., 2009). Also, this attribute is significant for conveyor width analysis and bottoms of storage equipment (Galedar et al., 2008).

Coefficient of static friction

The mean values for static coefficients of friction for the

Table 4. Test of significance on varietal differences.

No.	Physical properties (Parameter)	Computed F- ratio
1	Length	365.08
2	Width	397.97
3	Thickness	176.44
4	Dg	331.95
5	Sphericity	362.48
6	Surface Area	364.25
7	Bulk density	20.89
8	True density	17.59
9	Porosity	7.06
10	Angle of repose	2.94
11	Coefficient of Friction:	
	Glass	10.02
	Polished wood	77.02
	Galvanized steel	29.38

Table 5. LSD test for varietal difference on selected geometric properties.

Groundnut variety	Length		Width		Thickness		Dg		Sphericity	
	Mean	LSD	Mean	LSD	Mean	LSD	Mean	LSD	Mean	LSD
Obolo	18.92	a	9.63	a	10.23	a	12.28	a	65.21	a
Yenyawoso	12.35	b	7.82	b	8.24	b	9.25	b	75.26	b
CRI-Nkatie	13.64	c	7.79	b	8.4	b,c	9.62	c	70.79	c
Agbeyeyie	12.44	b	8.11	c	8.59	c	9.51	c	76.93	d
Pion	12.62	b	7.99	c	8.54	c	9.5	c	75.55	b

Means with the same letters are not significantly different.

kernel varieties on the three structural surfaces viz polished wood, galvanized steel and glass were 0.42, 0.46, and 0.39 for *Obolo*, 0.34, 0.34, and 0.32 for *Yenyawoso*, 0.32, 0.35 and 0.32 for CRI-*Nkatie*, 0.33, 0.35, 0.32 for *Agbeyeyie* and 0.33, 0.34, and 0.32 for *Pion,* respectively (Table 3). It was observed that the highest static coefficient of friction was found with galvanized steel and the least was found with glass in all the varieties studied. Coefficient of static friction has effect on the nature of the surface in contact with the kernel. An increase in frictional resistance was associated with rough surfaces as compared with smooth and polished surfaces. This observation depicts that the smoother and more polished the structural surface, the lower the static coefficient of friction of the samples and vice versa. The values obtained for this property concurs with findings from Baryeh (2001), Davies (2009) and Muhammad et al. (2015) for bamabara groundnut, groundnut grains, and groundnut pods and kernels, respectively. The design dimension of hoppers, bunker silos and other bulk solid storage and handling structures are dependent on the static coefficient of friction. This property is a significant bench mark for calculating the angle of inclination in inclined grain transporting equipment like chutes (Gharibzahedi et al., 2010). Coefficient of friction is a dependent variable needed for selecting materials for fabrication and power required for transporting a given biological material.

Analysis of variance on varietal differences

Table 4 depicts a test of variance performed on the means of the physical attributes to examine the deviations among means of the kernel varieties. There were apparent significant differences at $p \geq 0.05$ among the means of the physical attributes studied. The computed *F Critical* at 5% for all the parameters studied was 3.48. Except for the mean angle of repose; the properties for geometric, gravimetric, and frictional attributes were in variance. LSD was used to establish the veracity of differences among the means of the attributes as indicated in Tables 5 to 7. From Tables 5 to 7, the mean length, width, thickness, geometric mean diameter, sphericity and surface area of *Obolo* variety were statistically higher as compared to the other four

Table 6. LSD test for varietal difference on selected gravimetric properties.

Groundnut variety	Bulk density		True density		Porosity	
	Mean	LSD	Mean	LSD	Mean	LSD
Obolo	758.05	a	1004.43	a	24.53	a
Yenyawoso	797.77	b	1029.98	b,d	22.48	b,c
CRI-Nkatie	792.77	b	1020.73	c	22.34	b,c
Agbeyeyie	799.71	b	1024.33	b,c	21.96	b
Pion	792.79	b	1033.67	d	23.43	c

Means with the same letters are not significantly different.

Table 7. LSD test for varietal difference on selected frictional properties.

Groundnut variety	Glass		Galvanized steel		Polished wood	
	Mean	LSD	Mean	LSD	Mean	LSD
Obolo	0.39	a	0.46	a	0.42	a
Yenyawoso	0.32	b	0.34	b	0.34	b,c
CRI-Nkatie	0.32	b	0.33	b	0.32	b
Agbeyeyie	0.32	b	0.35	b	0.33	c
Pion	0.32	b	0.34	b	0.33	b,c

Means with the same letters are not significantly different

varieties. The mean bulk density, true density and porosity of *Yenyawoso*, *Cri-Nkatie, Agbeyeyie* and *Pion* were statistically similar but differ from *Obolo*. Similarly, the mean coefficient of friction on the glass, polished wood and galvanized steel for *Yenyawoso, CRI-Nkatie, Agbeyeyie* and *Pion* were statistically similar but differ from *Obolo*. These differences are very pertinent when deciding on designing of mechanical equipment for handling, processing and storage.

Conclusion

The study carried out on five groundnut varieties, namely, *Obolo*, *Yenyawoso*, *Cri-Nkatie, Agbeyeyie* and *Pion*, respectively, at moisture contents (% wet basis) of 7.2, 7.9, 7.8, 7.8 and 7.8 revealed the following results:

(1) Among the groundnut varieties studied, *Obolo* had the maximum geometric dimensions and this is evident on its physical appearance.
(2) For the 1000 mass grain and porosity, *Obolo* variety recorded extremely high values; however its bulk density was the least among the varieties studied.
(3) The results obtained for frictional properties indicate that the static coefficient of friction varies with the property of the frictional surfaces of the material and this was maximum for galvanized steel, followed by polished wood and glass surface for all the five varieties studied on the structural surfaces.
(4) The means of some of the physical attributes for the groundnut varieties studied were statistically different.
(5) Statistically, *Obolo* variety had geometrical properties different from the remaining four varieties studied. The implication is that, to design or select an equipment for cleaning, winnowing, conveying, storage and grading, these four varieties (*Yenyawoso*, *Cri-Nkatie, Agbeyeyie* and *Pion)* may use a single equipment for the pre-harvest and post-harvest operations as compared with *Obolo* variety which will require separate equipment for processing.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENTS

The authors thank Dr. James Y. Asibuo, Head, Legumes Improvement Program and other Co-workers at the unit of the Council for Scientific and Industrial Research-Crops Research Institute (CSIR-CRI), for their assistance in providing samples of the groundnut kernels for the experiment. They are indebted to the various authors whose works were advertently used and duly referenced. They also appreciate the team of the editorial board and the innominate reviewers for their constructive criticism in helping shape this write-up.

REFERENCES

Abano EE, Amoah KK (2011). Effect of moisture content on the physical properties of tiger nut (Cyperusesculentus). Asian Journal of Agricultural Research 5(1):56-66.

Akcali ID, Ince A, Guzel E (2006). Some physical properties of peanuts. International Journal of Food Properties 9:25-37.

Association of Official Analytical Chemists (AOAC) (1980). Official Methods of Analysis 13th Edition, Association of Official Analytical Chemists, Washington, DC.

Aviara NA, Power PP, Abbas T (2013). Moisture-dependent physical properties of Moringa oleifera seed relevant in bulk handling and mechanical processing. Industrial Crops and Products 42:96-104.

Bala BK (2017). Drying and storage of cereal grains (2nd Edition.). Chichester, UK: John Wiley & Sons, Ltd.

Baryeh EA (2001). Physical properties of bambara groundnuts. Journal of Food Engineering 47:321-326.

Boukouvalas Ch J, Krokida MK, Maroulis ZB, Marinos-Kouris D (2006). Density and Porosity: Literature data compilation for foodstuffs. International Journal of Food Properties 9(4):715-746.

Davies RM (2009). Some physical properties of groundnut grains. Journal of Applied Science, Engineering and Technology 1(2):10-13.

Davies RM (2010). Engineering properties of three varieties of melon seeds as potentials for development of melon processing machines. Advance Journal of Food Science and Technology 2(1):63-66.

El-Fawal YA, Tawfik MA, El-Shal AM (2009). Study on physical and engineering properties for grain of some field crops. Misr Journal of Agricultural Engineering 26(4):1933-1951.

Firouzi S, Vishgaei MNS, Kaviani B (2009). Some physical properties of groundnut (*Arachis hypogaea* L.) Kernel cv. NC2 as a function of moisture content. American-Eurasian Journal of Agricultural and Environmental Science 6(6):675-679.

Galedar MN, Jafari A, Tabatabaeefar A (2008). Some physical properties of wild pistachio (*Pistacia vera* L.) nut and kernel as a function of moisture content. International Agrophysics 22:117-124.

Gharibzahedi SMT, Mousavi SM, Moayedi A, Garavand AT, Alizadeh SM (2010). Moisture-dependent engineering properties of black cumin (*Nigella sativa* L.) seed. Agricultural Engineering International: CIGR Journal 12:1.

Jibril AN, Yadav KC, Abubakar MS, Bini IM (2016). Effect of moisture content on physical properties of bambara groundnut (Vigna subterranea L. Verdc.) seeds. International Journal of Engineering Research and Technology 5(7):248-258.

Khan NJ, Paramjit SP, Sukhcharn S (2019). Effect of moisture content on the physical and mechanical properties of quinoa seeds. International of Agrophysics 33:41-48.

Krishnappa M, Maddi A, Matamari V, Kulkarni P, Desai B, Vasudevan SN (2017). Engineering properties of selected groundnut (*Arachis Hypogea* L.) varieties. International Journal of Agricultural Science and Research 7(4):203-216.

Maduako JN, Hamman M (2005). Determination of some physical properties of three groundnut varieties. Nigerian Journal of Technology 24(2):12-18.

Mohsenin NN (1986). Physical properties of plant and animal materials (2nd Edition.). Gordon and Breach Science Publications, New York pp. 56-91.

Muhammad AI, Ahmad RK, Lawan I (2017). Effect of moisture content on some engineering properties of groundnut pods and kernels. Agricultural Engineering International 19(4):200-208.

Muhammad AI, Isiaka M, Fagge AA, Attanda ML, Lawan I, Dangora ND (2015). Some engineering properties of three varieties of groundnut pods and kernels. Arid Zone Journal of Engineering, Technology and Environment 11:61-75.

Odesanya KO, Adebiyi KA, Salau TAO (2015). Estimation of engineering parameters for the development of a groundnut decorticator. International Journal of Novel Research in Engineering and Applied Sciences 2(1):2-25.

Ofori H, Amoah F, Arah KI, Aidoo AI, Okley TN (2019). Moisture-dependent physical properties of Opeaburoo and Abontem maize varieties during drying. African Journal of Food Science 13(8):152-162.

Olajide JO, Igbeka JC (2003). Some physical properties of groundnut kernels. Journal of Food Engineering 58:201-204.

Serpil S, Servet GS (2006). Physical properties of foods. Springer Science and Business Media, LLC, New York, USA.

Stroshine R, Hamann D (1995). Physical properties of agricultural materials and food products. Department of Agricultural and Biological Engineering, West Lafayette pp. 30-89.

Vengaiah PC, Srivastav PP, Majumdar GC (2015). Research paper design related physical properties of major cereals. Research Paper Design Related Physical Properties of Major Cereals 4(1):1910-1914.