

# Physical Characterisation of Two Varieties of Bambara Groundnut Seeds

Ademola Kabir Aremu, Adejoke Mercy Ojo-Ariyo, Babatunde Olayinka Oyefeso\*

Department of Agricultural and Environmental Engineering, University of Ibadan, Ibadan, Nigeria.

Corresponding Author: [oyefesobabatunde@gmail.com](mailto:oyefesobabatunde@gmail.com)

## ARTICLE INFO

Received: March / 2022

Revised: May / 2022

Accepted: June / 2022

Published: June / 2022

**Keywords:** Physical characterisation, Bambara groundnut, Moisture content, Crop varieties, Processing, Handling

## ABSTRACT

Some physical attributes of two selected varieties of Bambara groundnut seeds grown in Nigeria were determined in this study. Standard methods were used to determine the selected properties which include linear dimensions, surface area, mass, volume, density, sphericity, porosity and coefficients of friction of the seeds on plywood, galvanized iron and aluminium surfaces. Length, width and thickness were within the ranges of 13.41-14.40 mm, 12.00-12.89 mm and 11.36- 11.99 mm, respectively for cream variety and 12.54-13.91 mm, 11.16-12.28 mm and 10.51-11.46 mm, respectively for light brown variety. Surface area of the seeds and volume were within the ranges of 507.94-588.45 mm<sup>2</sup> and 1077.59-1351.79 mm<sup>3</sup>, respectively for cream variety, and 443.05-880.63 mm<sup>2</sup> and 541.47-1191.18 mm<sup>3</sup>, respectively for light brown variety. The thousand seed mass ranged from 833.20 to 1116.93 g and 718.97 to 863.83 g for cream and light brown varieties respectively. Bulk density ranged from 0.71 to 0.79 g/cm<sup>3</sup> and 0.71 to 0.77 g/cm<sup>3</sup> for cream and light brown varieties respectively. The results showed that that the cream variety is larger and heavier than the light brown. Variations in true density and porosity of the seeds were sinusoidal in nature as moisture content increased for both varieties. Frictional coefficients on the three surfaces increased with moisture content. The investigated physical attributes were dependent on the amount of moisture in the seeds. The results from this study are useful in the development of handling and processing equipment for Bambara groundnut seeds.

## 1. INTRODUCTION

Bambara groundnut (*Vigna subterranean*) is an important legume which belongs to *Fabaceae* family (Alonge *et al.*, 2016). It is an under-utilized crop which provides security for many farmers in the tropics as it shows considerable drought resistance (Orhevba *et al.*, 2016). Bambara groundnut (BGN) is majorly produced in Nigeria and Ghana (Alakali and Satimehin, 2007). It is a very important source of protein although it is not accepted to be very lucrative as a cash crop (Fery, 2002; Aremu *et al.*, 2022). Some of its common names include jugo beans (South Africa), *njugumawe* (Swahili), *ntoyo* or *katoyo* (Republic of Zambia), *voanjobory* (Malagasy), *Kacang bogor* (Indonesia), *okpa* (Igbo, Nigeria), *Gurjiya* or Kwaruru (Hausa, Nigeria), *epakuta* (Yoruba, Nigeria) etc. Varieties and cultivars of BGN seeds include black, red, cream (no eye, black-eyed and brown eyed), speckled or spotted and brown varieties.

BGN is eaten by both man and livestock in various forms. It can be processed by different means such as frying or boiling. It can also be milled into flour for a varieties of food products. The seeds are used for medicinal purposes and for animal feeds (Heller *et al.*, 1997). BGN seeds are contained in pods which usually are developed under the ground. The seeds are usually stored in their shells or pods after harvesting so as to reduce susceptibility to weevil attack. Harvesting of the pod is usually done manually or by using local tools such as a hoe after which it is cleaned, dried and stored. Traditional methods and technologies are still largely employed in the processing of BGN such as harvesting, shelling, cleaning etc. Proper mechanization of the unit operations involved in BGN processing necessitates a sound knowledge of the physical characteristics of the seeds. The physical attributes of agricultural materials give a good description of the attributes of the materials. It is imperative to have an accurate estimate of these properties such as mass, linear dimensions, shape, size, volume, density, projected area, repose angle, porosity and frictional coefficient as they play significant roles in processing operations and design of machinery and equipment for such operations.

Agricultural materials have some unique properties such as non-uniformity of shape, non-homogeneity, anisotropy, dependence on temperature, age or maturity, moisture-dependence etc. Several researches have been carried out to investigate the moisture-dependent

physical properties of various agricultural materials such as pumpkin seed and kernel (Joshi *et al.*, 1993), benniseed (Olayanju, 2002), soybean (Polat *et al.*, 2006), pea seeds (Paksoy and Aydin, 2006), cowpea varieties (Davies and Zibokere, 2011), peanut kernels (Sayed *et al.*, 2011), melon (Bande *et al.*, 2012), *Detarium microcarpum* seeds (Aviara *et al.*, 2015) and pepper berries (Azman *et al.*, 2021). The knowledge of these important physical attributes of BGN seeds as affected by variation in moisture content is required to foster sound analysis of the behaviour of the seeds in handling and for proper design of equipment for sorting, handling and processing of the seeds. This study therefore, aimed at investigating some physical attributes of cream and light brown varieties of BGN seeds as influenced by moisture content levels.

## 2. METHODOLOGY

### 2.1. Preparation of the Samples

Two varieties of BGN seeds which were classified as cream and light brown were used in the study. Ten kilograms of each variety were acquired from *Aiyen* market, Kogi State, for the experiments. The seeds were cleaned before the determination of the initial Moisture Content (MC) by drying in an oven (Uniscope, SM 9053, England) at 130°C for 6 hours (ASAE 1983; Oluwole *et al.*, 2004).

### 2.2. Determination of the physical properties

BGN seeds of specified amount of moisture were prepared according to the method described by Baryeh (2001) which involved adding an amount of distilled water to the seeds which was calculated according to Equation 1 (Davies and Zibokere, 2011). The samples were packaged in polyethylene packs and preserved in a refrigerator (Haier Thermocool, China) for a week to ensure that the moisture in the seeds was uniformly distributed. All the measured physical attributes were determined at 5, 15, 25 and 35% MC dry basis (db) with three replications each (Baryeh, 2001).

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

Where: Q is mass of water added to seed (g),  $W_i$  is initial mass of sample (g),  $M_i$  and  $M_f$  are the initial and final moisture contents (% db), respectively.

At each moisture content, fifty randomly selected seeds were used. Linear dimensions of the seeds were measured using a digital vernier caliper (Carrera Precision, d = 2, CP5906). Arithmetic (AMD) and geometric (GMD) mean diameters were calculated using Equations 2 and 3 respectively (Raji and Oyefeso, 2021)

$$AMD = \frac{L+W+T}{3} \quad (2)$$

$$GMD = \sqrt[3]{LWT} \quad (3)$$

Where: L, W and T are the length (mm), width (mm) and thickness (mm), respectively.

Sphericity ( $\phi$ ) was determined using Equation 4 (Davies, 2010; Oyefeso, 2021). The volume of the seed (V) was determined using Equation 5 while and surface area (SA) was calculated according to Equation 6 respectively (Jain and Bal, 1997).

$$\phi = \frac{\sqrt[3]{LWT}}{L} \quad (4)$$

$$V = \frac{\pi B^2 L^2}{6(2L-B)} \quad (5)$$

$$SA = \frac{\pi B L^2}{2L-B} \quad (6)$$

Where:  $B = \sqrt[3]{WLT}$ .

A thousand seed mass was measured by weighing 100 seeds with the aid of an electronic weighting balance (Kerro digital scale, Taiwan, 0.1 g) and multiplying by 10. Bulk density of the seeds was calculated according to Equation 7 (Mohsenin, 1970; Oyefeso, 2021; Raji and Oyefeso, 2021).

$$\rho_B = \frac{M_s}{V_s} \quad (7)$$

Where:  $\rho_B$  is bulk density of the seeds ( $\text{gcm}^{-3}$ ),  $M_s$  is mass of the seeds in the graduated cylinder (g) and  $V_s$  is the volume occupied by the seeds ( $\text{cm}^3$ )

The true density of the seed was calculated as the ratio of the seed mass to the volume of water displaced (Omobuwajo *et al.*, 2000). Porosity was determined according to Equation 8 (Mohsenin, 1970).

$$P = \left(1 - \frac{\rho_B}{\rho_T}\right) \times 100 \quad (8)$$

Where: P is porosity of the sample and  $\rho_T$  is true density of the sample ( $\text{gcm}^{-3}$ ).

Angle of repose ( $R_a$ ) was determined based on Equation 9 (Özgüven and Vursavus, 2005; Karababa, 2006; Davies, 2010).

$$R_a = \tan^{-1}(2H/D) \quad (9)$$

Where: H and D are the height (mm) and diameter (mm) of the conical shape formed by the seeds (mm).

The coefficient of static friction for BGN seeds was determined on plywood, galvanized iron and aluminium surfaces according to the method described by Davies and Zibokere (2011) and calculated according to Equation 10.

$$\mu = \tan \alpha \quad (10)$$

where:  $\alpha$  = maximum angle of tilt before sliding.

The results obtained from the study were subjected to statistical analysis namely regression and analysis of variance (ANOVA).

### 3. RESULTS AND DISCUSSION

The investigated physical attributes of BGN seeds are presented in Table 1. The initial moisture content of the cream variety was 5.99% MC (db) while that of the light brown variety was 8.18% MC (db) respectively.

**Table 1: Measured Physical Properties of Bambara Groundnut Seeds**

Moisture Content (% db)	Variety	Length (mm)	Width (mm)	Thickness (mm)	AMD (mm)	GMD (mm)	Sphericity (%)	Surface area (mm <sup>2</sup> )	Volume (mm <sup>3</sup> )
5	Cream	13.41±0.57	12.00±0.58	11.36±0.50	12.26±0.49	12.19±0.49	90.94±1.43	507.9±43.49	1077.59±138.57
	Light Brown	12.54±0.86	11.16±0.74	10.51±0.62	11.40±0.70	11.34±0.70	90.50±1.50	443.05±56.67	880.63±165.90
15	Cream	13.78±0.55	12.36±0.63	11.77±0.43	12.63±0.49	12.57±0.48	91.25±1.20	537.46±46.20	1173.03±150.39
	Light Brown	13.02±0.73	11.71±0.54	11.14±0.54	11.96±0.57	11.90±0.56	91.41±1.90	481.50±46.97	995.42±145.82
25	Cream	14.25±1.06	12.76±0.87	11.84±0.87	12.95±0.88	12.88±0.87	90.43±2.08	575.73±78.26	1305.66±263.78
	Light Brown	13.83±1.02	12.20±0.80	11.56±0.80	12.53±0.77	12.46±0.75	90.19±2.36	534.26±75.99	1167.09±261.93
35	Cream	14.40±1.10	12.89±1.05	11.99±0.98	13.09±0.99	13.02±0.99	90.43±2.21	588.45±90.36	1351.79±309.24
	Light Brown	13.91±1.05	12.28±0.90	11.46±0.77	12.55±0.83	12.47±0.82	89.78±2.73	541.47±78.12	1191.18±263.25

#### 3.1. Seed dimensions

Length, width, thickness, AMD and GMD of the seeds increased with increasing moisture content within the range of 5 to 35% (db). The length increased from 13.41 to 14.40 mm for cream variety and 12.54 to 13.91 mm for light brown variety. The width also increased from 12.00 to 12.89 mm for the cream variety and 11.16 to 12.28 mm for light brown variety. The seeds increased in thickness from 11.36 to 11.99 mm for cream variety and 10.51 mm to 11.46 mm for light brown variety as moisture content increased. AMD increased from 12.26 to 13.09 mm for cream variety and from 11.40 to 12.55 mm for light brown variety. GMD increased from 12.19 to 13.02 mm for cream variety and from 11.34 to 12.47 mm for light brown variety. The ANOVA results showed that the linear dimensions measured were significantly different ( $p \leq 0.05$ ) at different moisture content levels for both varieties. Similar trends have been reported by Tavakoli *et al.* (2009) and Bamgboye and Adejumo (2009) for soybean and roselle seeds, respectively.

Variation in sphericity of BGN seeds with respect to moisture content was sinusoidal in nature. Sphericity of cream variety increased from 90.94 at 5% MC (db) to 91.25% at 15%, decreased to 90.43% at 25% MC (db) and remained the same at 35% MC (db). Sphericity of light brown variety also increased from 90.50 at 5% MC (db) to 91.41% at 15% MC (db), and decreased to 89.78% at 35% MC (db). The results were contrary to those reported for other seeds such as pigeon pea and jatropha by Baryeh and Mangope (2002) and Bamgboye and Adebayo (2012), respectively, probably due to differences in the shape and moisture content of the seeds.

Comparison of the results of the dimensions measured for both varieties clearly indicated that the cream variety is bigger than the light brown variety. The results of the sphericity also indicated that BGN seeds could be described as being spherical in shape (Garnayak *et al.*, 2008).

#### 3.2. Surface area and volume

The surface area and volume of the seeds increased from 507.94 mm<sup>2</sup> and 1077.59 mm<sup>3</sup> to 588.45 mm<sup>2</sup> and 1351.79 mm<sup>3</sup> respectively for cream variety, and from 443.05 mm<sup>2</sup> and 541.47 mm<sup>3</sup> to 880.63 mm<sup>2</sup> and 1191.18 mm<sup>3</sup> for light brown variety respectively, as moisture content increased. The cream variety had higher values of surface area and volume. ANOVA showed that the observed values of surface area and volume of the seeds at different moisture content levels were significantly different ( $p \leq 0.05$ ). Similar trends have been reported for some cowpea varieties (Davies and Zibokere, 2011).

3.3. A thousand seed mass

The variation in the 1000 seed mass of BGN seeds for both varieties is presented in Figure 1. The seed mass of the cream and light brown varieties increased as the seed moisture content increased. The seed mass increased from 833.20 g for cream variety and 718.97 g for light brown variety at 5% MC (db) to 1116.93 g and 863.83 g at 35% MC (db) for the cream and brown varieties respectively. The results were significantly different ( $p \leq 0.05$ ) for both varieties. Similar trends were reported for jatropha and melon seeds (Garnayak *et al.*, 2008; Bande *et al.*, 2012).

Equations 11 and 12 represent the relationship established between 1000 seed mass and moisture content.

$$M = 10.05 \times mc + 790.5 \quad R^2 = 0.949 \text{ for cream variety} \quad (11)$$

$$M = 4.521 \times mc + 673.9 \quad R^2 = 0.753 \text{ for light brown variety} \quad (12)$$

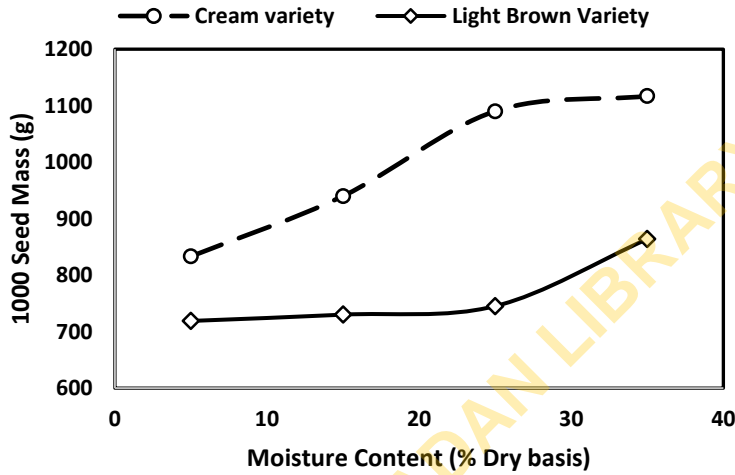


Figure 1: A thousand seed mass of BGN

3.4. True and bulk densities

Bulk density and true density of BGN seeds are shown in Figures 2 and 3, respectively. The bulk densities decreased from 0.79 to 0.71  $\text{gcm}^{-3}$  and 0.77 to 0.71  $\text{gcm}^{-3}$  for cream and light brown varieties respectively. The cream variety had higher bulk densities for all the moisture levels considered. This is similar to the report given by Davies and Zibokere (2011) for three varieties of cowpea and Carman (1996) for lentil seeds. Equations 13 and 14 represent the relationships established for bulk density based on moisture content.

$$\rho_B = -0.284 \times mc + 0.807 \quad R^2 = 0.987 \text{ for cream variety} \quad (13)$$

$$\rho_B = -0.242 \times mc + 0.787 \quad R^2 = 0.946 \text{ for light brown variety} \quad (14)$$

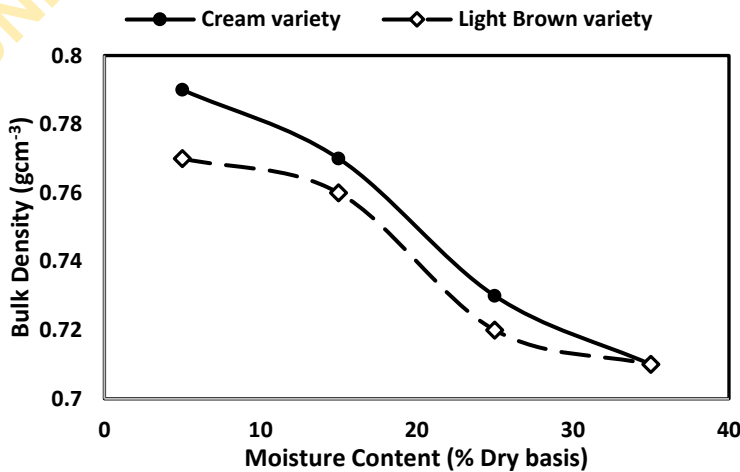


Figure 2: Bulk density of BGN seeds

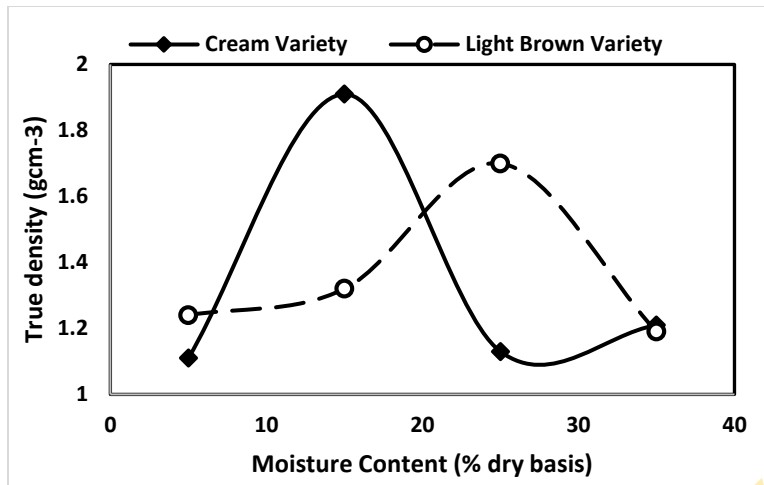


Figure 3: True density for BGN seeds

True density increased from 1.11 to 1.91 gcm<sup>-3</sup> as moisture content increased from 5 to 15% and decreased to 1.13 gcm<sup>-3</sup> at 25% and later increased to 1.21 gcm<sup>-3</sup> at 35% MC (db) for cream variety. For light brown variety, true density increased from 1.24 to 1.70 gcm<sup>-3</sup> as moisture content increased from 5 to 25% and decreased to 1.19 gcm<sup>-3</sup> at 35% MC (db). Similar findings were reported by Hojat *et al.* (2009) for fennel seed and Tunde-Akintunde and Akintunde (2007) for benniseed. Equations 15 and 16 showed the relationship established for true density with respect to moisture content.

$$\rho_T = 0.0004 \times mc^3 - 0.026 \times mc^2 + 0.472 \times mc - 0.645 \quad R^2 = 1.000 \text{ for cream variety} \quad (15)$$

$$\rho_T = -0.0002 \times mc^3 + 0.010 \times mc^2 - 0.136 \times mc + 1.684 \quad R^2 = 1.000 \text{ for light brown variety} \quad (16)$$

### 3.5. Porosity

The variation of porosity of BGN seeds is presented in Figure 4. Porosity increased from 28.77% at 5% MC (db) to 59.55% at 15% MC (db) and decreased to 35.34% at 25% moisture content and afterwards increased to 41.56% at 35% MC (db) for the cream variety. For light brown variety, porosity increased from 37.54% at 5% MC (db) to 57.72% at 25% moisture content and later reduced to 40.84% at 35% MC (db). The results for light brown variety are similar to those reported for cowpea (Davies and Zibokere, 2011).

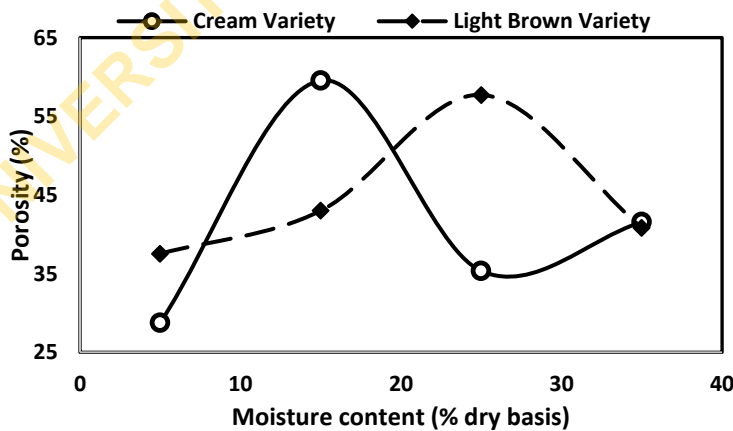


Figure 4: Porosity of BGN seeds

### 3.6. Angle of repose

Variations in angle of repose of the seeds are shown in Figure 5. Angle of repose of the seeds decreased from 12.62° at 5% to 9.10° at 15% MC (db) and then increased to 13.90° at 25% MC (db) with a subsequent reduction to 12.72° at 35% MC (db) for the cream variety. For the light brown variety, angle of repose increased linearly from 11.43° at 5% to 15.14° at 35% MC (db). Equations 17 and 18 show the relationships established for angle of repose for BGN varieties based on moisture content.

$$R_a = -0.0024 \times mc^3 + 0.149 \times mc^2 - 2.554 \times mc + 21.969 \quad R^2 = 1.000 \text{ for cream variety} \quad (17)$$

$$R_a = 0.224 \times mc + 9.520 \quad R^2 = 0.982 \text{ for light brown variety} \quad (18)$$

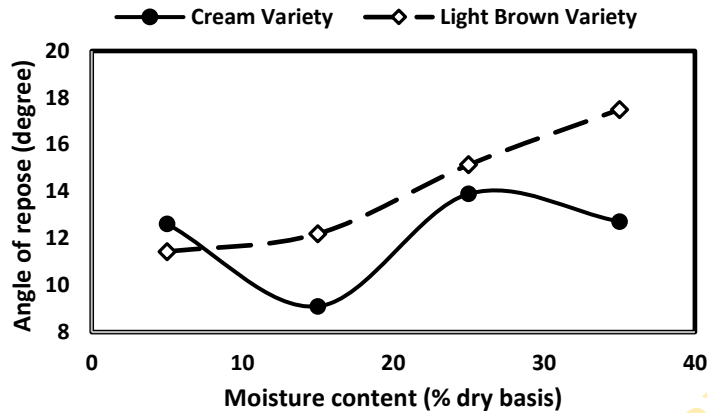


Figure 6: Angle of repose for BGN seeds

### 3.7. Coefficient of friction

Variations in the coefficient of friction of BGN seeds on the three plane surfaces are presented in Figures 6 and 7. The coefficient of friction of the seeds increased on all contact surfaces as moisture content increased. For cream variety, coefficient of friction on plywood surface increased from 0.1733 to 0.2924, from 0.1352 to 0.2044 on galvanized iron surface and from 0.1317 to 0.2717 on aluminium surface. For light brown variety, it increased from 0.2451 to 0.4791, 0.2428 to 0.4706 and 0.1817 to 0.3839 on plywood, galvanized iron and aluminium surfaces, respectively. The maximum values were obtained on plywood (0.2924 for cream and 0.4791 for light brown variety) while the minimum values were obtained on aluminium (0.1317 and 0.1817 for cream and light brown varieties respectively). Similar results have been reported for pumpkin seeds and jatropha (Joshi *et al.*, 1993; Bamgboye and Adebayo, 2012). The relationships established for coefficient of friction based on moisture content are shown in Equations 19 to 24 for different varieties on the three surfaces considered.

$$\mu_p = 0.361 \times mc + 0.146 \quad R = 0.830 \text{ for cream variety} \quad (19)$$

$$\mu_g = 0.480 \times mc + 0.108 \quad R = 0.929 \text{ for cream variety} \quad (20)$$

$$\mu_a = 0.453 \times mc + 0.104 \quad R = 0.929 \text{ for cream variety} \quad (21)$$

$$\mu_p = 0.755 \times mc + 0.179 \quad R = 0.867 \text{ for light brown variety} \quad (22)$$

$$\mu_g = 0.732 \times mc + 0.180 \quad R = 0.871 \text{ for light brown variety} \quad (23)$$

$$\mu_a = 0.685 \times mc + 0.143 \quad R = 0.996 \text{ for light brown variety} \quad (24)$$

where  $\mu_p$ ,  $\mu_g$  and  $\mu_a$  are the coefficients of friction on plywood, galvanized iron and aluminium, respectively.

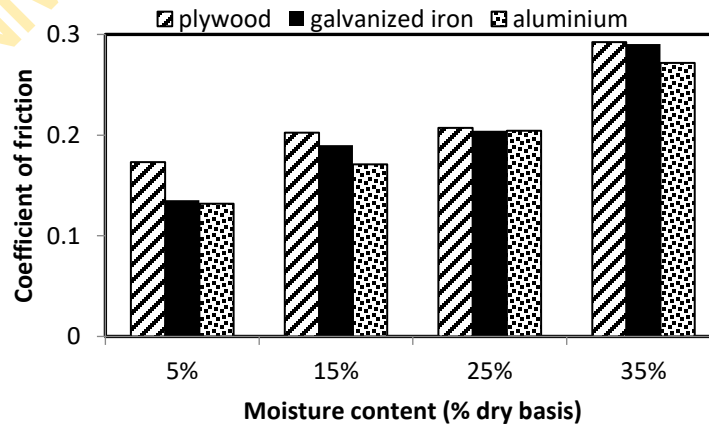


Figure 6: Coefficient of friction on different contact surfaces for cream variety

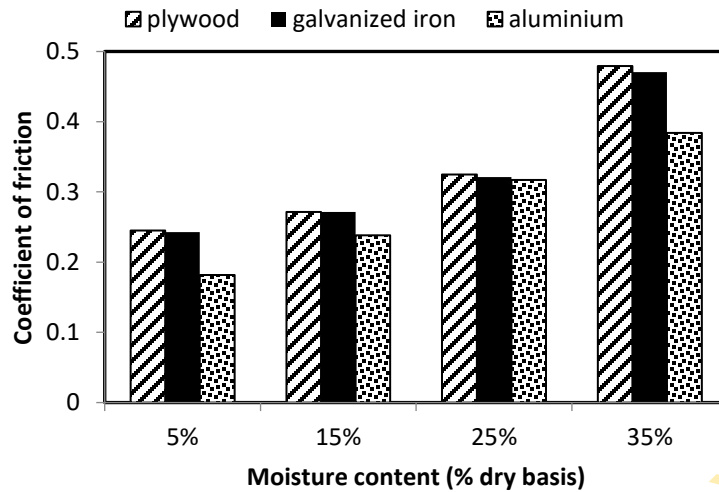


Figure 7: Coefficient of friction on different contact surfaces for light brown variety

#### 4. CONCLUSION

Some physical attributes of two selected cultivars of Bambara groundnut seeds were determined in the study. Linear dimensions, 1000 seed mass, surface area and volume increased with moisture content for both varieties. Coefficient of friction was highest on plywood and lowest on the aluminium surface. All the investigated physical attributes were moisture-dependent. These properties are useful for the development of equipment for handling and processing of the seeds.

#### References

- Alakali, J. S. and Satimehin, A. A. (2007). Moisture Adsorption Characteristics of Bambara Groundnut (*Vigna subterranea*) Powders. *Agricultural Engineering International: the CIGR Ejournal*. Manuscript FP 07 005. Vol. IX.
- Alonge, A. F., Basse, E., Esua, O. J. and Onwude, D. I. (2016). Development and Preliminary Testing of a Bambara Groundnut Sheller. *International Food Research Journal* 23(Suppl): S7-S13.
- Altuntas, E. and Yildiz, M. (2007). Effect of Moisture Content on Some Physical and Mechanical Properties of Faba Bean (*Vicia faba* L.) Grains. *Journal of Food Engineering*, 78: 174–183.
- Aremu, A. K., Ojo-Ariyo, A. M. and Oyefeso, B. O. (2022). Selected mechanical properties of Bambara groundnut seeds under compressive loading. *LAUTECH Journal of Engineering and Technology (LAUJET)*, 16(1): 70-77.
- ASAE (American Society of Agricultural Engineers) (1983). Moisture Measurement: Grains and Seeds. In: ASAE Standards, St. Joseph, MI, USA.
- Aviara, N. A., Onaji, M. E. and Lawal, A. A. (2015). Moisture-dependent Physical Properties of *Detarium microcarpum* Seeds. *Journal of Biosystems Engineering*, 40(3): 212-223.
- Azman, P. N. M. A., Shamsudin, R., Che-Man, H. and Ya'acob, M. E. (2021). Mass modelling of pepper berries (*Piper nigrum* L.) with some physical properties. *Food Research*, 5(Suppl. 1): 80-84. doi:10.26656/fr.2017.5(S1).047
- Bangboye, A. I. and Adebayo, S. E. (2012). Seed Moisture Dependent on Physical and Mechanical Properties of *Jatropha curcas*. *Journal of Agricultural Technology*, 8(1): 13-26.
- Bangboye, A. I. and Adejumo, I. O. (2009). Physical Properties of Roselle (*Hibiscus sabdariffa* L.) Seed. *Agricultural Engineering International: the CIGR Ejournal*. Manuscript 1154. Vol. XI.
- Bande, Y. M., Adam, N. M., Azm, I. Y. and Jamarei, O. (2012). Determination of Selected Physical Properties of Egusi Melon (*Citrullus colocynthis* L.) Seeds. *Journal of Basic and Applied Science*, 8: 257-265.
- Baryeh, E. A. (2001). Physical properties of Bambara groundnuts. *Journal of Food Engineering*, 47(4): 321-326.
- Baryeh, E. A. and Mangope, B. K. (2002). Some Physical Properties of QP-38 Variety Pigeon Pea. *Journal of Food Engineering*, 56: 59-65.
- Carman, K. (1996). Some Physical Properties of Lentil Grains. *Journal of Agricultural Engineering Research*, 63(2): 87–92.
- Davies, R. M. (2010). Some Physical Properties of Arigo Seed. *International Agrophysics*, 24: 89-92.
- Davies, R. M. and Zibokere, D. S. (2011). Effect of Moisture Content on Some Physical and Mechanical Properties of the Three Varieties of Cowpea. *CIGR Journal*, 13(1): 1-16.

- 16 Fery, R. L. (2002). New opportunities in Vigna. In: Trends in New Crops and New Uses, Eds J. Fanick and A. Whipkey, 424-428. Alexandria: ASHS Press.
- 17 Garnayak, D. K., Pradhan, R. C., Nalk, S. N. and Bhatnagar, N. (2008). Moisture-dependent Physical Properties of Jatropha Seed. Industrial Crops and Products, 27: 127-129.
- 18 Heller, J., Begemann, F., and Mushonga, J. (1997). Bambara Groundnut (*Vigna Subterranea* (L.) Verdc., In Proceedings of the Workshop on Conservation and Improvement of Bambara Groundnut (*Vigna subterranea* (L.) Verdc.), 14-16 November 1995, Harare, Zimbabwe.
- 19 Hojat, A., Kaveh, M. and Jalal, K. (2009). Some Physical and Mechanical Properties of Fennel Seed (*Foeniculum vulgare*). Journal of Agricultural Science, 1:1-10.
- 20 Ibrahim, Y. (2007). Physical Properties of Cowpea (*Vigna Sinensis* L) Seed. Journal of Food Engineering, 79: 57-62.
- 21 Jain, R. K. and Bal, S. (1997). Properties of Pearl Millet. Journal of Agricultural Engineering Research, 66: 85-91.
- 22 Joshi, D. C., Das, S. K., and Mukherjee, R. K. (1993). Physical properties of pumpkin seeds. Agricultural Engineering Research, 54: 219-229.
- 23 Karababa, E. (2006). Physical properties of popcorn kernels. Journal of Food Engineering, 72: 100-110.
- 24 Mohsenin, N. N. (1970). Physical Properties of Plant and Animal Materials. Gordon and Breach Science Publishers, New York.
- 25 Olayanju, T. M. A. (2002). Design, Fabrication and Evaluation of a Benniseed (*Sesamum indicum* L.) Oil Expeller. Doctoral Thesis, University of Ibadan, Ibadan, Nigeria.
- 26 Oluwole, F. A., Aviara, N. A. and Haque, M. A. (2004). Development and Performance Tests of a Sheanut Cracker. Journal of Food Engineering, 65: 117-123.
- 27 Omobuwajo, T. O., Sanni, L. A., and Balami, Y. A. (2000). Physical Properties of Sorrel (*Hibiscus sabdariffa*) Seeds. Journal of Food Engineering, 45: 37- 41.
- 28 Orhevba, B. A, Adejumo, B. A. and Julius, O. P. (2016). Determination of some Selected Engineering Properties of Bambara Nut (*Vigna subterranea*) Related to Design of Processing Machines. IOSR Journal of Agriculture and Veterinary Science (IOSR-JAVS) 9(6): 42-47.
- 29 Oyefeso, B. O. (2021). Size and Shape Characterisation of *Tacca involucrata* Tubers. LAUTECH Journal of Engineering and Technology, 15(1): 34-38.
- 30 Özgüven, F. and Vursavus, K. (2005). Some Physical, Mechanical and Aerodynamic Properties of Pine (*Pinus pinea*) Nuts. Journal of Food Engineering, 68(1): 191-196.
- 31 Paksoy, M. and Aydin, C. (2006). Determination of Some Physical and Mechanical Properties of Pea (*Pisum sativum* L.) Seeds. Pakistan Journal of Biological Science, 9:26-29.
- 32 Polat, R., Atay, U. and Saglam, C. (2006). Some Physical and Aerodynamic Properties of Soybean. Journal of Agronomy, 5(1): 74-78.
- 33 Raji, A. O. and Oyefeso, B. O. (2021). Prediction of Mass and Volume of *Tacca involucrata* Tubers Using Physical Characteristics. Arid Zone Journal of Engineering, Technology and Environment, 17(3): 415-428.
- 34 Sayed, H. P., Fatemeh, R. A., Iraj, B. and Mohammad, R. A. (2011). Effect of moisture content on some engineering properties of peanut varieties. Journal of Food, Agriculture and Environment, 9(3-4): 326-331.
- 35 Tavakoli, H., Rajabipour, A., and Mohtasebi, S. S. (2009). Moisture-dependent some engineering properties of soybean grains. Agricultural Engineering International: CIGR EJournal, Manuscript 1110, Vol. XI.
- 36 Tunde-Akintunde, T. Y., and Akintunde, B. O. (2007). Effect of Moisture Content and Variety on Selected Properties of Benniseed: Agricultural Engineering International: CIGR EJournal, 9(1): 1-13.