Effect of moisture content on some engineering properties of groundnut pods and kernels

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Abstract: Effect of moisture content on some engineering properties of groundnut pods and kernels were investigated. Two groundnut varieties were used namely: *Manipintar* and *Ex-Dakar*. The properties investigated were principal dimensions, porosity, bulk density, true density, angle of repose and static coefficient of friction as dependent variables while moisture content is the independent variable. At an increasing moisture content of 7.3%-25.2% d.b., the mean length, thickness, width, geometric mean diameter, arithmetic mean diameter and surface area for *Ex-Dakar* pods were 30.6-33.46, 12.55-14.89, 12.8-14.03, 16.88-18.71, 18.61-20.75 mm and 904.86-1099.73 cm^2, respectively. The corresponding mean values for the *Manipintar* pods were 18.60-30.89, 11.62-15.01, 11.72-14.05, 13.63-18.68, 13.98-19.98 mm and 583.78-1095.80 cm^2, respectively. However, for *Ex-Dakar* kernels, the mean length, thickness, width, geometric mean diameter, arithmetic mean diameter and surface area recorded within moisture range of 8.5%-28.1% were 12.92-13.01, 8.81-9.35, 10.73-11.71, 10.72-11.14, 10.82-11.36 mm and 360.96-389.68 cm^2, respectively. Similarly, mean values for the *Manipintar* kernels were 18.60-30.89, 11.62-15.01, 11.72-14.05, 8.97-11.03, 9.19-11.38 mm, and 252.89-382.16 cm^2, respectively. The porosity for *Ex-Dakar* pods increased from 30.23%-61.77% and from 11.65%-18.63% for the kernels, from 31.37%-59.41% and 11.65%-33.82% for *Manipintar* pods and kernels. True density increased from 0.35-0.72 and 0.84-1.13 g cm^{-3} for *Ex-Dakar* pods and kernels, from 0.39-0.62 and 0.98-1.29 g cm^{-3} for *Manipintar* pods and kernels. However, the bulk density showed a decrease from 0.33-0.24 and 0.92-0.55 g cm^{-3} for *Ex-Dakar* pods and kernels, and from 0.53-0.21 and 1.12-0.75 g cm^{-3} for *Manipintar* pods and kernels. Angle of repose increased from 25.1-28.9^o and 24.7-27.1^o for *Ex-Dakar* pods and kernels, and for *Manipintar* pod and kernels, it increased from 26.3-29.5^o and 25.0-29.0^o. The mean static coefficient of friction on plywood, galvanize sheet and glass increased at varying moisture contents for both pods and kernels. The establishment of these parameters would serve as reference that is required to achieve the desired results in successful design and operation of groundnut processing equipment.

Keywords: engineering properties, groundnut varieties, moisture content, angle of repose

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1 Introduction

Groundnut, sometimes referred as peanut or earthnut (*Arachis hypogea Linnaeus*), is an herbaceous plant species with its pods growing underneath the soil. It is widely cultivated in warm climates and currently grown on nearly 22.2 million hectares worldwide with a total production of 35 million tons. Groundnut is of two major varieties; bunch and runner varieties. The bunch varieties are common in the United States, grow 30-40 cm in height and do not spread. Then, the runner varieties which is the most common in West Africa, are shorter and run along the ground for 30-60 cm. Apart from the above mentioned varieties, many intermediate hybrids exist (Muhammad et al., 2015). The crop is an important source of protein in human diet and livestock feeds; the kernels are rich in edible oil (43%-55%) and protein (25%-28%), and the shells is a good raw material for

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insulation, fuel and fertilizer (Payman et al., 2011). The cake after oil extraction is used as animal feed, in fact no part of groundnut is a waste.

The major moisture-dependent physical properties of biological materials are shape and size, bulk density, true density, porosity, mass of fruits, angle of repose and friction against various surfaces. These properties have been studied for various crops: Millet (Baryeh, 2002; Bart-Plange and Baryeh, 2003), Groundnut (Firouzi *et al*., 2009), Sweet seeds (Simonyan et al., 2009), paddy rice (Adebowale et al., 2011), Walnut (Altuntas and Erkol, 2010) and Apricot Pit (Shahbazi, 2012). Properties related to design of groundnut handling equipment were investigated in various literatures. Among which are physical dimensions, geometric mean diameter, sphericity and density, angle of repose, coefficient of static friction on different surfaces all determined at 4.6% moisture content (Olajide and Igbeka, 2003). Similarly, properties for peanut pods and its kernel at moisture content of 8.25% and 10.03% (dry basis) respectively were determined in (Dilmac and Altuntas, 2012), for Samnut 10, Samnut 14 and Samnut 18 determined 8% moisture content (Fashina et al., 2014).

Payman et al. (2011) stated that at different processing stages, groundnut passes several ranges of moisture content namely: 35% moisture content under the soil, 15%-25% at harvesting time depending on environmental conditions and management strategy, and 18%-24% at threshing time. Furthermore, the moisture content should be reduced to 7% before storage. Considering the different levels of moisture content groundnut undergoes and the rapid seed deterioration it encounters during storage, Alam et al., (2013) emphasized on the need to investigate some engineering properties of groundnut as affected by the moisture content changes. Such properties include: length, thickness and width, geometric mean diameter, sphericity, unit mass, volume, surface area, bulk and true density, angle of repose, porosity and static coefficient of friction and also rupture strength. The knowledge would be used in designing of various handling equipment for pneumatic conveying, separating, shelling, drying, and storage of the product.

The aim of the study was to determine some engineering properties of groundnuts commonly cultivated in Northwestern Nigeria as the basis for the redesign and improvement of local groundnut handling equipment. This has become necessary looking at the prevalent low-quality kernels from groundnut processing clusters which poses risk of kernels contaminations.

2 Materials and Methods

2.1 Materials used in the study

Some of the materials used in the study includes; digital slide vernier caliper, digital balance, graduated measuring cylinders of different sizes, vacuum oven, angle of repose measuring apparatus, pycnometer, steel sheet, plywood, glass, two groundnut varieties; *Ex-Dakar* and *Manipintar.*

2.2 Sampling

The groundnut varieties selected were *Ex-Dakar* and *Manipintar*. These were believed to be the commonest varieties in the local market of the study area (*Dawanau* market of Kano Sate, Nigeria) during the year 2016. The samples were to remove all foreign matter such as dust, debris, stones, and immature pods and kernels.

2.3 Determination of Engineering Properties

2.3.1 Determination of Moisture Content

The initial moisture content was determined using ASABE standard (2008) described in (Payman et al., 2011) on dry basis. Triplicate samples (pods and kernels) of 200 g for each variety were dried in air convection oven set at temperature of 100 ± 3°C and monitored for a period of 72 hrs. At the end moisture content was calculated on dry basis using the relationship described by Simonyan et al. (2009):

$$MC_{wb} = \frac{W_i - W_d}{W_i} \times 100 \tag{1}$$

where, MC_{wb} = Moisture content (% w.b.); W_i = Initial mass of groundnuts (kg), and W_d = dry mass of the samples (kg).

Furthermore, desired moisture levels of the groundnuts to conduct the experiment were prepared by adding the required amount of distilled water calculated from the given relationship:

$$Q = \frac{W_i(M_f - M_i)}{100 - M_f} \tag{2}$$

where, W_i, M_i and M_f are the initial mass (g), initial moisture content (% d.b.) and final moisture content of the groundnut samples (% d.b.), respectively. Prior to conducting each experiment, the required amount of samples were taken out of refrigerator and allowed to equilibrate with room temperature for about 2 hrs (Firouzi et al., 2009).

The resultant moisture contents of groundnut were 7.3, 10.2, 14.1, 23.5 and 25.2 % d.b. for the pods and 8.5%, 10.2%, 13.6%, 25.4% and 28.1% d.b. for kernels for the two varieties. All the physical properties of the groundnut were determined at these moisture levels with three replications at each level.

2.3.2 Determination of Principal Dimensions

The three principal dimensions (length width and thickness) of each groundnut pods and kernels were determined by measurements using digital slide Vernier calipers on one hundred samples of groundnut pods and kernels for each variety and at three different moisture content levels.

The Geometric Mean Diameter (GMD) and Arithmetic Mean Diameter (AMD) of pods and kernels were calculated according to the relationship obtained from (Mohsenin, 1986; Payman et al., 2011).

$$D = (LWT)^{1/3} \tag{3}$$

$$D_a = \frac{(L + W + T)}{3} \tag{4}$$

2.3.3 Determination of Surface area

The surface area, A was calculated in accordance with Odesanya et al. (2015) as:

$$A = \pi D^2 \, (\text{cm}^2) \tag{5}$$

where, D = Geometric mean diameter (cm).

2.3.4 Determination of Porosity

The porosity (P) of the groundnut pods and kernels at different moisture contents were calculated from the mean values of bulk density (ρ_b) and true density (ρ_T) using the relationship obtained in (Davies, 2009):

$$P = 1 - \frac{\rho_b}{\rho_T} \tag{6}$$

2.3.5 Determination of Bulk Density

The bulk density was determined by filling a graduated cylinder of 500 mL with the groundnuts up to its brim from a height of about 150 mm and the excess was removed by striking off the top with stick and weighing the contents of cylinder. The bulk density (ρ_b) of groundnut pods and kernels was then calculated by dividing the mass (M) to the volume (V_b) of 500 mL (Aydin, 2007).

$$\rho_b = \frac{M}{V_b} \tag{7}$$

2.3.6 Determination of True Density

True density of the groundnut pods and kernels was determined by liquid displacement method (using toluene; C_7H_8 as the liquid). Toluene was used because it has lower surface tension and lower specific mass when compared to water. The volume of sample and true density (ρ_T) were calculated using the Equations 8 and 9 respectively as given by (Altuntas and Erkol, 2010; Payman et al., 2011):

$$V_s = \frac{M_{td}}{\rho_{tolu}} = \frac{(M_{tp} - M_p) - (M_{pts} - M_{ps})}{\rho_{tolu}} \tag{8}$$

$$\rho_T = \frac{M_{ps} - M_p}{V_s} \tag{9}$$

where, V_s = Volume of sample (m^3); M_{td} = weight of displaced toluene (g); ρ_{tolu} = density of toluene (kg m^{-3}); M_{tp} = weight of pycnometer and toluene (g); M_p = weight of pycnometer (g); M_{pts} = weight of pycnometer, toluene and sample (g); M_{ps} = weight of pycnometer and sample (g).

2.3.7 Determination of Angle of Repose

The angle of repose was determined by using wooden box and two plates; fixed and adjustable. The wooden box was filled with the groundnut sample and the adjustable plate was gradually lifted until the material start to slide over the inclined surface at this point the angle of inclination was recorded as the angle of repose for the groundnut samples (Muhammad et al., 2015).

2.3.8 Determination of Static Coefficient of Friction

The static coefficient of friction of groundnut pods and kernels against three different surfaces; namely steel sheet, plywood, and glass was determined using a wooden frame (10 cm×10 cm×6 cm) without base and lid which was placed over different surfaces and filled with the groundnut sample. The sample was poured in the box on the surface to be lifted for inclination from the horizontal. The angle of inclination of the surface was increased gradually until the box with the content just started to slide down. This angle between the inclined surface and the horizontal was measured, the tangent of which gave the static coefficient of friction as stated in Equation (10). This method was used by other researchers like (Gupta and Das, 1997; Baryeh, 2002; Bart-Plange and Baryeh, 2003).

$$\mu_s = \tan\varphi \qquad (10)$$

where, μ_s = static coefficient of friction; φ = angle between the inclined surface and the horizontal at which samples just start to slide down. Three replications for each groundnut sample were made.

3 Results and Discussion

3.1 Sizes Dimension

3.1.1 Principal Dimensions of the two groundnut varieties

Table 1 showed the means of physical properties of groundnut pods and kernels for *Ex-Dakar* variety. It could be seen that the length, width and thickness for the pods were presented at various moisture contents with length ranging from 30.6-33.46 mm, width ranging from 12.55-14.89 mm and thickness ranging from 12.8-14.03 mm all recorded at 7.3% and 25.2% moisture content, respectively. Similarly, the length, width and thickness recorded for *Ex-Dakar* groundnut kernels were in the range of 12.92-13.01 mm, 8.81-9.35 mm, 10.73-11.71 mm at moisture content of between 8.5%-28.1%, respectively. These results were similar to that reported by (Payman et al., 2011). However, for *Manipintar* in Table 2, the length, width and thickness for the pods were presented at various moisture levels with length ranging from 18.60-30.89 mm, 11.62-15.01 mm, and 11.72-14.05 mm at moisture levels ranging from 7.3%-25.2%, respectively. Similarly, for the kernels, the length, width and thickness were recorded in the range of 12.10-15.50 mm, 8.11-9.87 mm, and 7.36-8.77 mm at moisture range of between 8.5%-28.1%, respectively. Similar result was reported by Firouzi (2009). In comparing the two varieties, it could be deduced that the sizes of *Manipintar* in terms of length, width and thickness were larger than that of *Ex-Dakar*.

Table 1 Some Physical Properties of *Ex-Dakar* Groundnut Variety at different moisture contents

Physical properties	Sample number, N	Moisture content, % d.b.									
		Groundnut Pods					Groundnut Kernels				
		7.3	10.2	14.1	23.5	25.2	8.5	10.2	13.6	25.4	28.1
Length, L (mm)	20	30.6 (6.72)	30.97 (5.43)	31.55 (6.21)	32.12 (6.02)	33.46 (5.37)	12.92 (1.27)	12.91 (3.51)	12.96 (3.21)	12.99 (4.71)	13.01 (5.07)
Width, W (mm)	20	12.55 (1.57)	13.06 (2.23)	13.9 (3.39)	14.78 (3.87)	14.89 (2.68)	8.81 (2.11)	8.9 (1.75)	8.87 (1.94)	9.13 (2.10)	9.35 (2.37)
Thickness, T (mm)	20	12.8 (3.29)	13.23 (2.57)	13.67 (3.10)	14.01 (2.31)	14.03 (1.98)	10.73 (1.54)	11.01 (1.79)	11.23 (2.45)	12.03 (2.43)	11.71 (2.07)
GMD (mm)	20	16.88 (2.77)	16.98 (2.53)	17.67 (2.70)	18.23 (3.01)	18.71 (3.11)	10.72 (1.81)	10.79 (2.31)	10.82 (1.23)	11.05 (1.89)	11.14 (2.02)
AMD (mm)	20	18.64 (2.59)	19.1 (3.21)	19.32 (3.41)	20.37 (3.74)	20.75 (3.86)	10.82 (1.75)	10.94 (2.10)	11.02 (2.32)	11.38 (2.53)	11.36 (3.01)
Sphericity, S	20	0.57 (0.08)	0.61 (0.09)	0.61 (0.08)	0.62 (0.07)	0.62 (0.08)	0.83 (0.09)	0.84 (0.08)	0.84 (0.07)	0.87 (0.09)	0.86 (0.07)
Area, A (cm^2)	20	904.86 (196.03)	905.76 (193.10)	980.87 (187.50)	1044.02 (188.97)	1099.73 (189.23)	360.96 (53.59)	365.91 (49.34)	367.81 (57.12)	383.75 (50.16)	389.68 (55.15)

Note: Standard deviations are in parenthesis.

The geometric mean diameter (GMD) and arithmetic mean diameter (AMD) obtained at moisture contents of 7.3%-25.2% ranged from 16.88-18.71 mm and 18.61-20.75 mm for the pods, respectively whereas the corresponding kernels ranged from 10.72-11.14 mm for GMD and 10.82-11.36 mm for AMD and were obtained at moisture contents of 8.5%-28.1%, respectively (Table 1). This property of groundnut pods and kernels tended to increase as moisture level increased. Similar result was reported by Odesanya et al. (2015) for *Ex-Dakar* groundnut variety. Furthermore, from Table 2, the GMD and AMD obtained for *Manipintar* groundnut pods were in the range of 13.63-18.68 mm and 13.98-19.98 mm at moisture levels between 7.3%-25.2%, respectively. Similarly, the corresponding GMD and AMD for the kernels ranged from 8.97-11.03 mm and 9.19-11.38 mm at moisture levels between 8.5%-28.1%, respectively. The result was slightly different from that reported by Odesanya et al. (2015) for Samnut 22 and *Ex-Dakar* groundnut varieties. However, knowing this property is of paramount important in the selection of concave size for designing of shelling or decorticating and separation machines. Conclusively, *Manipintar* variety has larger GMD and AMD than that of *Ex-Dakar*. When processing the two varieties, both will require different concave size.

Table 2 Some Physical Properties of *Manipintar* Groundnut Variety at different moisture contents

Physical properties	Sample number, N	Moisture content, % d.b.									
		Groundnut Pods					Groundnut Kernels				
		7.3	10.2	14.1	23.5	25.2	8.5	10.2	13.6	25.4	28.1
Length, L (mm)	20	18.60 (2.09)	20.70 (3.21)	25.19 (3.89)	28.97 (4.01)	30.89 (5.70)	12.10 (3.26)	13.05 (2.75)	13.85 (3.12)	14.72 (3.40)	15.50 (2.68)
Width, W (mm)	20	11.62 (1.96)	12.55 (3.30)	13.49 (3.12)	14.84 (3.54)	15.01 (2.09)	8.11 (1.81)	8.45 (2.09)	8.65 (2.52)	8.97 (2.33)	9.87 (2.20)
Thickness, T (mm)	20	11.72 (1.97)	12.46 (3.47)	12.70 (3.90)	13.90 (2.99)	14.05 (2.75)	7.36 (0.98)	7.54 (1.45)	7.63 (2.30)	8.63 (1.87)	8.77 (1.73)
GMD (mm)	20	13.63 (2.98)	14.79 (4.10)	16.28 (3.08)	18.15 (3.62)	18.68 (3.15)	8.97 (1.57)	9.40 (2.09)	9.71 (3.01)	10.44 (3.20)	11.03 (3.43)
AMD (mm)	20	13.98 (3.41)	15.24 (4.12)	17.13 (4.36)	19.24 (4.57)	19.98 (3.78)	9.19 (1.22)	9.68 (2.31)	10.04 (3.00)	10.77 (1.97)	11.38 (2.41)
Sphericity, S	20	0.73 (0.09)	0.71 (0.08)	0.65 (0.07)	0.63 (0.09)	0.60 (0.08)	0.74 (0.08)	0.72 (0.09)	0.70 (0.07)	0.71 (0.08)	0.71 (0.09)
Area, A (cm^2)	20	583.78 (98.08)	687.44 (103.92)	832.75 (106.76)	1034.54 (105.23)	1095.80 (109.32)	252.89 (45.76)	277.79 (52.13)	295.90 (50.78)	342.73 (49.65)	382.16 (63.10)

Note: Standard deviations are in parenthesis.

3.1.2 Surface Area

The surface area for the pods (Table 1) ranged from 904.86-1099.73 cm^2 at a moisture range of 7.3%-25.2% while for the kernels, it ranged from 360.96-389.68 cm^2 at moisture range of between 8.5%-28.1%, respectively. The surface area showed an increase when the moisture content increased. Similar trend was observed in Aydin (2007). However, for *Manipintar* variety (Table 2), the surface area ranged from 583.78-1095.80 cm^2 for the pods at moisture ranges of 7.3%-25.2% while the surface area ranging from 252.89-382.16 cm^2 at moisture content between 8.5%-28.1% were for the kernels. This is in accordance with the results obtained by Aydin (2007).

3.2 Porosity

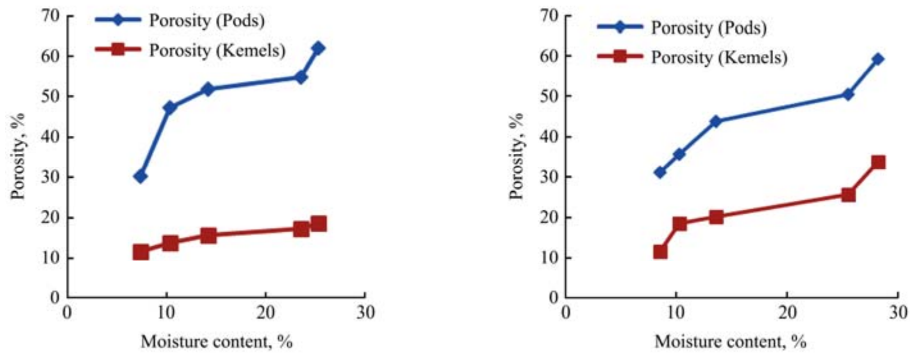
The porosity for *Ex-Dakar* groundnut pods and kernels (Figure 1a) increased from 30.23%-61.77% within a moisture range of 7.3%-25.2% and from 11.65%-18.63% in a moisture range of 8.5%-28.1%, respectively. Similarly, the porosity for *Manipintar* variety for pods and kernels (Figure 1b) ranged from 31.37%-59.41% within a moisture content of 7.5%-25.2% and from 11.65%-33.82% in moisture range of 8.5%-28.1%, respectively. It could be seen that the porosity for both groundnut varieties increased with the increase of moisture content. This finding was in conformity with what was reported by Aydin (2007) and Payman et al. (2011). It could be observed from the graphs that the porosity for *Ex-Dakar* groundnut variety was slightly higher that of *Manipintar* variety.

3.3 True Density

The true density for *Ex-Dakar* groundnut pods increased with the increase of moisture content and it varied from 0.35-0.72 g cm^{-3} when the moisture increased from 7.3%-25.2% (Figure 2a). Similarly, the true density for the kernels changed from 0.84-1.13 g cm^{-3} within the range of 8.5%-28.1% (Figure 2a). However, true density for *Manipintar* pods and kernels were shown in Figure 3. It ranged from 0.39-0.62 g cm^{-3} for the pods within the moisture range of 7.3%-25.2% (Figure 3a). Furthermore, the kernels' true density ranged from 0.98-1.29 g cm^{-3} within ranged of 8.5%-28.1%. This same trend was observed in Firouzi (2009).

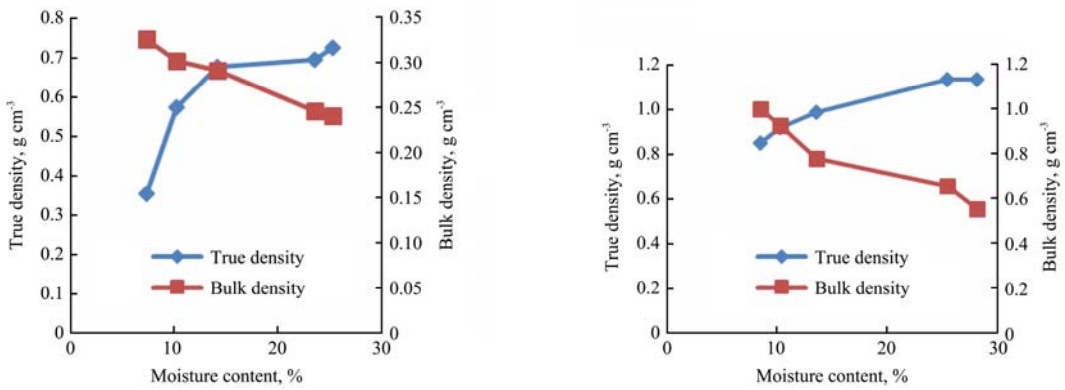
3.4 Bulk Density

The bulk density of *Ex-Dakar* pods decreased from 0.33-0.24 g cm^{-3} when the moisture content increased from 7.3%-25.2% (Figure 2a). This was also applied to the kernels where a decrease in bulk density from 0.92-0.55 g cm^{-3} was recorded from a corresponding increase in moisture content from 8.5%-28.1% (Figure 2b). On the other hand, bulk density of *Manipintar* pods decreased from 0.53-0.21 g cm^{-3} when the moisture increased from 7.3%-25.2% (Figure 3a). Likewise, for the kernels, with a moisture range of 8.5%-28.1%, it decreases from 1.12-0.75 g cm^{-3} (Figure 3b). This trend has been reported by many researchers (Aydin, 2007; Firouzi, 2009; Payman et al., 2011).



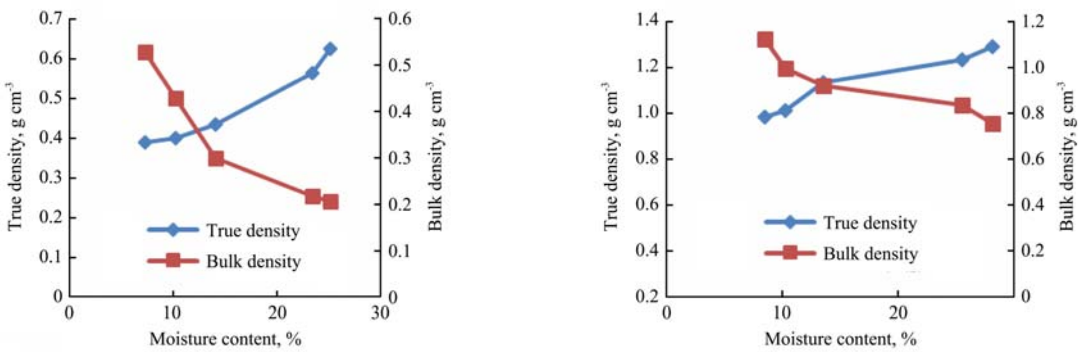
a. *Ex-Dakar* b. *Manipintar*

Figure 1 Effect of moisture content on Porosity for *Ex-Dakar* and *Manipintar* groundnut varieties



a. Groundnut pods b. Groundnut kernels

Figure 2 Effect of moisture content on True and Bulk densities for *Ex-Dakar* groundnut pods and kernels



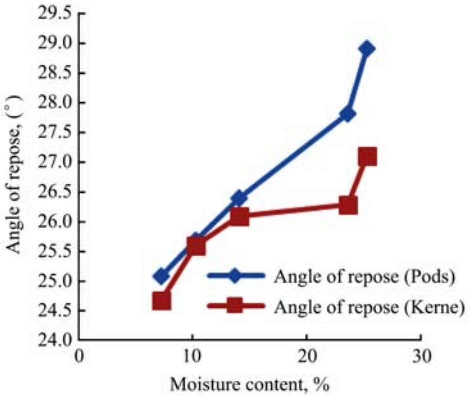
a. Groundnut pods b. Groundnut kernels

Figure 3 Effect of moisture content on True and Bulk densities for *Manipintar* groundnut pods and kernels

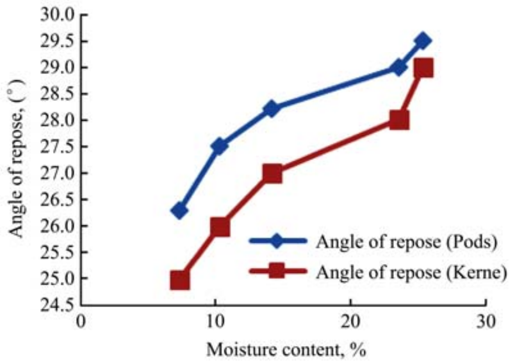
3.5 Angle of Repose

Figure 4a showed the angle of repose for *Ex-Dakar* groundnut variety. The angle of repose increased from 25.1-28.9^o in line with increase in moisture contents from 7.3%-25% for the groundnut pods, similarly with a moisture increment from 8.5%-28.1% of the groundnut kernels, the angle of repose also increased from 24.7-27.1^o. The maximum value of angle of repose (28.9^o) for the pods was slightly lower than that (28.4^o) reported by Odesanya et al. (2015) at 11.11% moisture content.

However, for *Manipintar* variety, the increase in moisture content from 7.3%-25% resulted in an increase for the pods from 26.3-29.5°. This was the case with groundnut kernels as moisture content increased from 8.5%-28.1%, there was a corresponding increase from 25.0-29.0° of angle of repose (Figure 4b). Similar increasing trend was also reported by Firouzi (2009).



a. *Ex-Dakar*



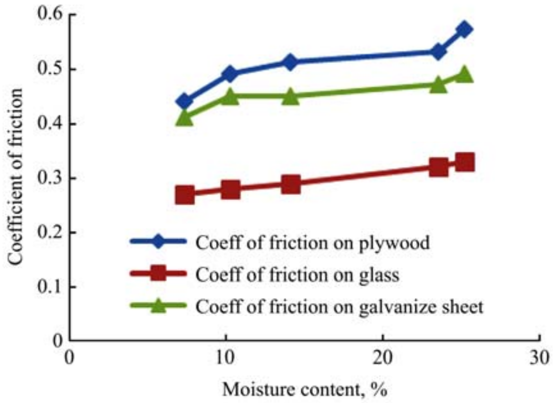
b. *Manipintar*

Figure 4 Effect of moisture content on angle of repose for *Ex-Dakar* and *Manipintar* variety

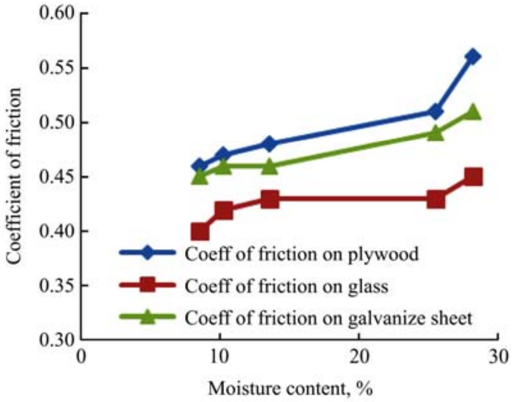
3.6 Static coefficient of friction

The static coefficient of friction of *Ex-Dakar* variety on plywood, glass and galvanize sheet were presented in Figure 5. The static coefficient of friction for the pods (Figure 5a) increased from 0.46-0.59 for plywood, 0.43-0.51 for galvanized sheet, and 0.31-0.41 for glass with the increasing moisture content from 0.73%-25.2%. This was also applied to the kernels (Figure 5b) in which the static coefficient of friction increased from 0.45-0.56, 0.45-0.51, and 0.40-0.45 for plywood, galvanized sheet and glass at an increasing moisture levels of 8.5%-28.1%, respectively. It could be observed from the result that the static coefficient of friction for plywood was higher than that of galvanized sheet and glass.

The static coefficient of friction for *Manipintar* variety presented in Figure 6 indicated an increase on all the surfaces. The increase of coefficient of friction between moisture levels might be explained by the increase in cohesive force of wet groundnuts with the surface, because the surface become stickier as moisture content level increased. The static coefficient of friction for plywood (0.44-0.57) was higher than for galvanized sheet (0.41-0.49) and glass (0.27-0.33) in the moisture range of 7.3%-25.2% (Figure 6a). Also for kernels, plywood has the highest coefficient of friction (0.47-0.53), followed by galvanized sheet (0.42-0.47) and glass has the lowest (0.31-0.36). All these values were within moisture range of 8.5%-28.1%. This trend was in agreement with many researchers (Aydin, 2007; Firouzi, 2009; Payman et al., 2011).

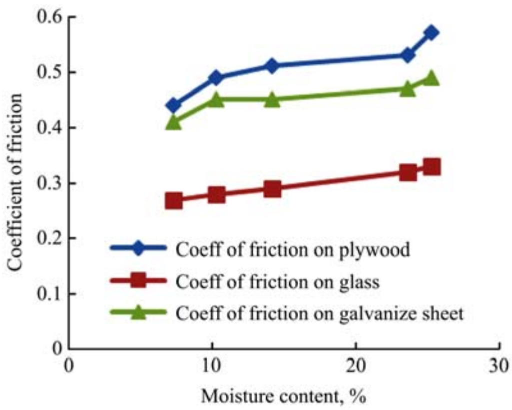


a. Groundnut pods

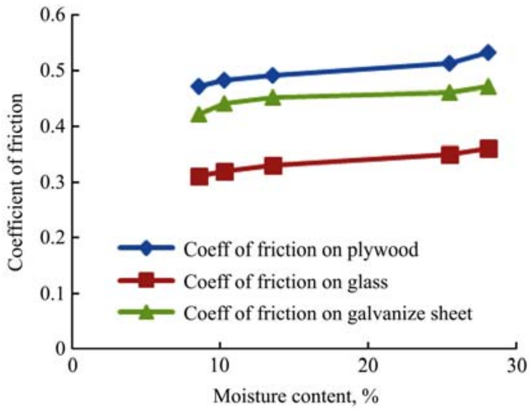


b. Groundnut kernels

Figure 5 Effect of moisture content on static coefficient of friction on different materials for *Ex-Dakar* groundnut pods and kernels



a. Groundnut pods



b. Groundnut kernels

Figure 6 Effect of moisture content on static coefficient of friction on different materials for *Manipintar* groundnut pods and kernels

4 Conclusion

The effect of moisture content on some engineering properties of two groundnut varieties was investigated. 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 irrespective of the variety. However, the bulk density decreased with the increase in moisture content for both varieties. 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. On the other hand, the least static coefficient of friction was on glass among the three surfaces investigated. And this was found to increase with increase in moisture content of the groundnuts pods and kernels. The study of moisture dependent properties of agriculture products is of paramount importance as these guarantee an extended shelf life. The safety of processed products like groundnut lies in the moisture content at which it was handled. Very high and very low moistures may compromise the quality of groundnuts, leading to damage, insect pest attack and possible contamination during handling operations and storage.

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References

Adebowale, A. A., L. O., Sanni, H. O., Owo, and O. R., Karim. 2011. Effect of variety and moisture content on some engineering properties of paddy rice. Journal of Food Science and Technology, 48(5): 551–559.

Alam, M. M., M. M., Rahman, M. A., Samad, R., Ashrafi, and M. M., Rahman. 2013. Effect of storage container and initial seed moisture content on quality of shelled groundnut seed. Journal of Agroforestry and Environmen, *7*(1): 23–26.

Altuntas, E., and M. Erkol. 2010. Physical properties of shelled and kernel walnuts as affected by the moisture content. Czech Journal of Food Sciences, 28(6): 547–556.

Aydin, C. 2007. Some engineering properties of peanut and kernel. Journal of Food Engineering, 79(3): 810–816.

Bart-Plange, A., and E. A. Baryeh. 2003. The Physical Properties of Category B Cocoa Beans. The Physical Properties of Category B Cocoa Beans, 60(3)*:* 219–227.

Baryeh, E. A. 2002. Physical properties of Millet. Journal of Agricultural Engineering Research, 51(1): 39–46.

Davies, R. M. 2009. Some Physical Properties of Groundnut Grains. Research Journal of Applied Sciences, Engineering and Technology, 1(2): 10–13.

Dilmac, M., and E. Altuntas. 2012. Selected some engineering properties of peanut and its kernel. International Journal of Food Engineering, 8(2): 1168-1174.

Fashina, A. B., A., Saleh, and F. B. Akande. 2014. Some engineering properties of three selected groundnut (Arachishypogaea L.) varieties cultivated in Nigeria. CIGR Journal, 16(4): 268–277.

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

Gupta, R. K., and S. K., Das. 1997. Physical properties of Sunflower seeds. Journal of Agricultural Engineering Research, 66(1): 1–8.

Mohsenin, N. N. 1980. *Physical properties of plant and animal* *materials* (*2nd ed*.). New York: Gordon and Breach Science Publisher.

Muhammad, A. I., M., Isiaka, A. A., Fagge, M. L., Attanda, I., Lawan, and N. D., Dangora. 2015. Some Engineering properties of three varieties of Groundnut pods and kernels. Arid Zone Journal of Engineering, Technology and Environment, 11: 61–75.

Odesanya, K. O., K.A., Adebiyi, and T. A. O., Salau. 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.

Olajide, J. O., and J. C., Igbeka 2003. Some physical properties of groundnut kernels. Journal of Food Engineering, 58(2): 201–204.

Payman, S. H., F. R., Ajdadi, I., Bagheri, and M. R., Alizadeh. 2011. Effect of moisture content on some engineering properties of peanut varieties. Journal of Food Science and Technology, 48(5): 551–559.

Shahbazi, F. 2012. Effects of Moisture Content , Impact Direction and Impact Energy on the Cracking Characteristics of Apricot Pit. World Applied Sciences Jurnal 20(11): 1520–1528.

Simonyan, K. J., Y. D., Yiljep, O. B., Oyatoyan, and G. S., Bawa. 2009. Effect of Moisture Content on Some Physical Properties of *Lablab Purpureus* (L.). CIGR journal, 11: manuscript No. 1279, XI.