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Note

Moisture-dependent physical properties of soybeans

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A b s t r a c t. Experiments were carried out to determine the moisture-dependent physical properties of soybeans as useful parameters in the designing of equipment for processing, transportation, sorting and separating soybeans. The physical properties of soybeans were determined at 9.5 to 49.7% (d.b.) moisture content. The grain dimensions as well as a thousand grain mass increased with increase in moisture content whereas bulk density, true density, porosity and sphericity decreased. The static angle of repose increased linearly from 30 to 51°. Also static coefficient of friction increased from 0.220 to 0.300 and 0.330 to 0.420 for glass and plywood surface with the increase of water content.

K e y w o r d s: soybean, physical properties, moisture content

INTRODUCTION

Soybean otherwise known as *Glycine max merilli* is regarded as one of the best answers to the shortage of protein and calories deficient in the diet of many million of people in various parts of the world (Oyekan, 1991). Soybean is considered as one of most important cereal grains in Nigeria. It contains about 40% protein and 20% cholesterol-free oil (Desphande *et al*., 1993). Soybean is becoming a preeminent cheap source of protein and edible oil in Africa as a whole as other protein supplying foods are increasingly becoming very expensive (such as milk, fish, meat and eggs). According to Adewale *et al*. (2005) reported that threshing and other unit operations have been identified as a major bottleneck to soybean production by most farmers especially small-medium scale farmers. It determines the hectarage of soybean a farmer cultivate. Most of the farmers threshed manually the soybean pods with heavy stick. To alleviate manual unit operations, low cost but efficient equipment should be developed locally.

To develop appropriate equipment for harvesting, handling, conveying cleaning, delivering, separation, packing, storing, drying, mechanical oil extraction and proceeding of agricultural products, their physical properties have to be known (Aviara *et al*., 1999; Mohsenin, 1980). The physical properties of soybean include the size, mass, bulk density, true density, sphericity, porosity, coefficient of static friction and angle of repose are moisture depending parameters. (Manuwa and Afuye, 2004; Razari *et al*., 2007) stated that moisture dependent characteristic of agricultural products have effect on the adjustment and performance of processing equipment. The physical properties have been studied for various agricultural products by other researchers such as soybean (Manuwa and Afuye, 2004), bambara groundnut (Adejumo, *et al*., 2005), caper fruit (*Capparis* spp), Sessiz *et al*., 2005) cocoa bean (Bart-Plange and Baryeh, 2002), pigeon pea (Shepherd and Bhardwaj (1986), locust bean seed (Ogunjimi *et al*., 2002), wheat (Tabatabaeefar, 2003) and pistachio nut and its kernel (Razari *et al.,* 2007).

This study was therefore carried out to determine the geometric and frictional properties of soybean as a function of moisture content.

MATERIALS AND METHODS

The soybeans used in the study were bought from Swali market in Yenegoa in Bayelsa State, Niger Delta, Nigeria. The samples were selected and cleaned manually. It was ensured that the grains were free of dirt, broken ones and other foreign materials. The experiments were conducted in the moisture range of 9.5-49.7% (d.b.). The initial moisture content of the grains was determined using ASAE (1998) standard S 352.2 involving the oven-drying method. Three

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samples each weighing 15 g was placed in an oven set at 103% for 72 h. The samples were cooled in a dessicator, reweighed and the moisture content of the seeds calculated. Physical properties were determined at the initial moisture. Thereafter, grains samples of the desired moisture level were prepared by adding calculated amount of distilled water and sealed in separate polythene bags. The grain was kept in refrigerator at a temperature of 5°C for one week to enable the moisture to distribute uniformly Razari *et al*. (2007). Prior to the experiment, the samples were taken out of the refrigeration and allowed to warm up to room temperature for two hours. All the physical properties of soybean were investigated at moisture level of 9.5, 14.4, 19.8, 31.6, 37.2, 42.9, and 49.7%. Ten replications of each test were made of each moisture level. For each of the moisture level, 100 soybean grains were randomly selected for measurement of length (L), width (W) and thickness (T) using a micrometer screw gauge with a reading of 0.01 mm. The geometric average diameter of soybean grain was calculated according Galedar *et al*. (2008) and Mohsenin (1986). The sphericity φ (%) was calculated with use the relationship described by Koocheki *et al*. (2007) and Milani (2007). The surface area (S) of soybean grain was found by analogy with a sphere of the same geometric mean diameter using the expression cited by Sacilik *et al*. (2003). The 100 unit mass was determined using precision electronic balance to an accuracy of 0.01 g. The grain volume, V_s and true density, ρ_t as a function of moisture content were determined by water displacement method (Adejumo *et al.,* 2005; Shepherd and Bhardwaj, 1986). A bunch of 100 grains of known average weight was dropped into a container filled with water. The weight of displaced water was used to calculate equivalent volume of water and thus volume of the grain. The grains were not coated to prevent water adsorption due to the short duration of experiment since it did not result in a significant increase in mass as reported by (Tunde-Akintunde and Akintunde, 2007). The true density was determined from mass and volume of 100 grains. The bulk density was determined by using the standard test weight procedure (Dutta *et al.,* 1988). This was achieved by filling a container of 500 ml with grain from the height 0.15 m striking the top level and then weighing the contents and the bulk density was determined from the measured mass and volume (Shepherd and Bhardwaj, 1986) for each moisture content, 10 replications were done and the average was taken. The porosity (ε) of the bulk grain was computed from the values of the true density (ρ_t) and bulk density (ρ_t) of the grains by using the relationship given by Mohsenin (1986).

The static coefficient of friction for soybean grains determined with respect to two test surfaces namely plywood and glass. A glass box of 150 mm length, 100 mm width and 40 mm height without base and lid was filled with sample and placed on an adjustable tilting plate, faced with test surface. The sample container was raised slightly (5-10 mm) so as not to touch the surface. The inclination of the test surface was increased gradually with a screw device until the box just started to slide down and the angle of tilt was measured from a graduated scale. For each replicate, the sample in the container was emptied and refilled with a new sample (Joshi *et al.,*1993). The static coefficient of friction (μ_s) was calculated based on Mohsenin (1986).

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

RESULTS AND DISCUSSION

The mean dimensions, geometric and arithmetic mean diameter, sphericity and surface area of soybean measured at different moisture contents ranged from 9.5 to 49.7% (d.b.) are given in Table 1. The three axial dimensions were observed to be increasing with increase in moisture content due to the absorption of moisture by the grain. In the sample,

Table 1. Some physical properties of soybean grains

Properties (mm)	Moisture content (%, d.b.)						
	9.5	14.4	19.8	31.6	37.2	42.9	49.7
Length	6.53 (1.02)*	6.73 (1.05)	7.13 (1.72)	7.25 (1.32)	7.49 (1.08)	7.65 (1.07)	7.96 (1.32)
Width	5.21 (0.98)	5.31 (1.02)	5.57 (0.89)	5.60 (1.04)	5.71 (0.09)	5.77 (0.87)	6.06 (1.41)
Thickness	4.28 (0.67)	4.29 (0.45)	4.35 (0.57)	4.40 (0.43)	4.51 (0.58)	4.57 (0.64)	4.94 (0.91)
Arithmetic mean diameter	5.34 (0.98)	5.44 (1.17)	5.68 (1.34)	5.75 (1.22)	5.89 (1.05)	6.00 (1.10)	6.40 (1.26)
Geometric mean diameter	5.26 (0.87)	5.35 (1.13)	5.57 (0.49)	5.63 (0.36)	5.78 (0.72)	5.86 (0.84)	6.18 (0.97)

*Standard deviation values in parentheses.

about 76% had lengths in the range of 6.5 to 7.5 mm, about 68% had widths in the range of 5.5 to 6 mm, and about 63% had a thickness in the range of 4.3 to 4.6 mm. Analysis of variance ANOVA results showed that the difference among moisture levels were statistically significant at the level of 0.05 for the three parameters. This increase in linear dimension was also observed for soybeans variety var (TG 1871-5E) and kano white variety of bambara groundnut as was reported by Manuwa and Afuye (2004) and Adejumo *et al.* (2005), respectively.

The sphericity (Φ) was found to decrease from 80.5 to 76.4% with increase in moisture content (Fig. 1). The difference among the sphericity values were statistically significant ($P<0.05$). The increase in sphericity with increase in moisture content agrees with the report of Manuwa and Afuye (2004) for soybean grain but contradicts the report of Adejumo *et al.* (2005) on variety of bambara groundnut.

Surface area (*S*) increased with increase in moisture content from 34.04 to 48.00 mm^2 (Fig. 1). The values were significantly different ($P<0.05$). The figure indicated that the surface area increased linearly with increasing in moisture content. Similar trend have been reported by Aviara *et al*. (1999) for guna seed, Tunde-Akintunde and Akintunde (2007) for beniseed and Sacilik *et al*. (2003) for hemp seed.

The bulk density (ρ_b) of the grains were observed to decrease from 870.7 to 808.5 kg m^{-3}(Fig. 2). This can be attributed to fact that an increase in mass owing to moisture gain in the grain sample was lower than the accompanying volumetric expansion of the bulk. A similar decreasing trend was observed by Desphande *et al*. (1993) for JS 7244 variety of soybean, and Dutta *et al*. (1988) for gram.

The true density (ρ_t) decreased from 1236.7 to 940.4 kg m^{-3} with increasing moisture content. The true density has a negative linear relationship with moisture content. The negative relationship was also observed by Manuwa and Afuye (2004) for soybean and Shepherd and Bhardwaj (1986) for pigeon pea which contradicts Gupta and Das (1997) for sunflower seed and Suthar and Das (1996) for karingda seeds that reported increase in true density with increase in moisture content. The bulk density was observed to be lower than the true density. This could be adduced to air spaces in grain bulk that increases the volume while the mass is the same. This is similar to the observation of Manuwa and Afuye (2004).

The porosity(ε') of the bulk decreased from 30 to 14% with increase in the moisture content (Fig. 3). This decrease in porosity with increase in moisture content was also observed by (Tunde-Akintunde and Akintunde, 2007) for beniseed, Dutta *et al.* (1988) for gram and Aviara *et al.* (1999) for guna seed. This observation was contrary to Manuwa and Afuye (2004) for soybean that reported that porosity increases with increase in moisture content.

The results of repose angle of soybean at different moisture content are shown in Fig 3. The angle of repose of soybean ranged from 30 to 51° with increase in moisture

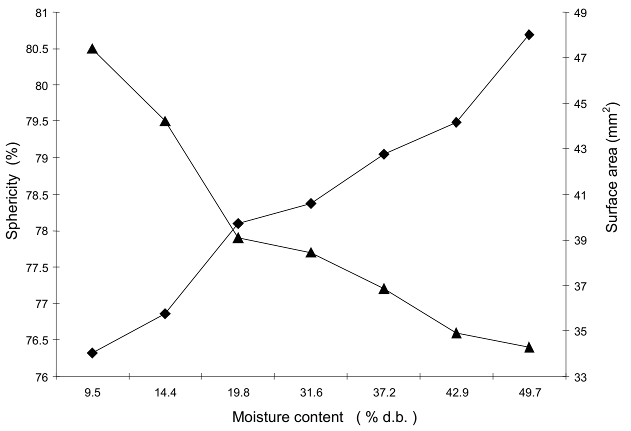

Fig. 1. Effect of moisture content on sphericity and surface area of soybean grains, ■ – sphericity, ◆ – surface area.

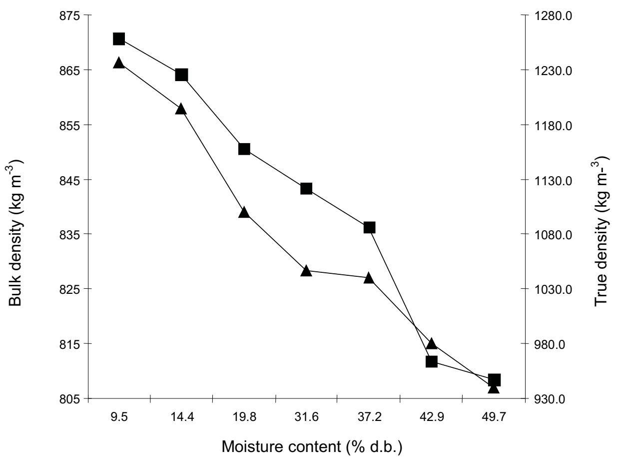

Fig. 2. Effect of moisture content on bulk density and true density of soybean grains, ■ – bulk and ◆ – true densities.

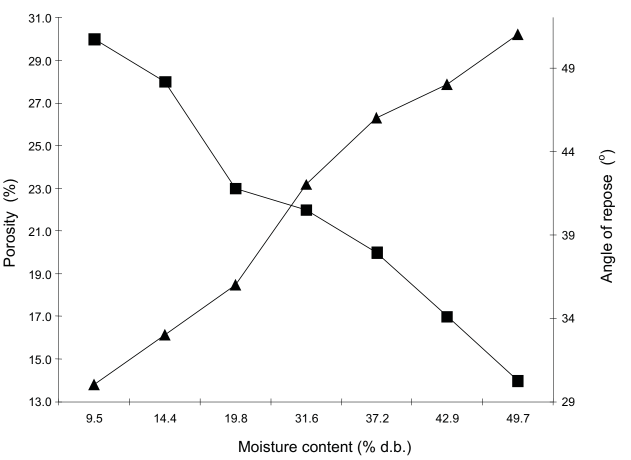

Fig. 3. Effect of moisture content on pororsity and angle of repose of soybean grains, ■ – porosity, ◆ – angle of repose.

content dry basis. The observed increase in angle of repose of soybean with increase in moisture content was reported by Jha and Prasad (1993) for gorgon seed, Amin *et al.* (2004) for lentil seeds and Razari *et al.* (2007) for wild pistachio nut and its kernel.

The 1 000 grain mass increased from 122.0 to 169.4 g with increase in the moisture content. The relationship between the moisture content and the thousand grain mass increased linear from 122 to 169.4 g (Fig. 4).

Figure 5 shows the static coefficient of friction for soybean with respect to plywood (μ_p) and glass surfaces (μ_g) at different moisture contents. The coefficient of static friction of glass ranged from 0.22 to 0.30, while plywood ranged from 0.33 to 0.42. At all the moisture contents, the static coefficient of plywood was the highest. The reason for the increased friction coefficient at higher moisture level might be attributed to the moisture adsorption by the grain creating cohesive force on the surface in contact. The static coefficient of friction increased with increase in moisture content for the two surfaces. The effect of the moisture content of soybean on static coefficient of friction against glass and plywood showed positive linear relationship. Other researchers had reported that as the moisture content increases, the static coefficient of friction increases as well (Gupta and Das, 1997; Razari *et al*., 2007; Tunde-Akintunde and Akintunde, 2007).

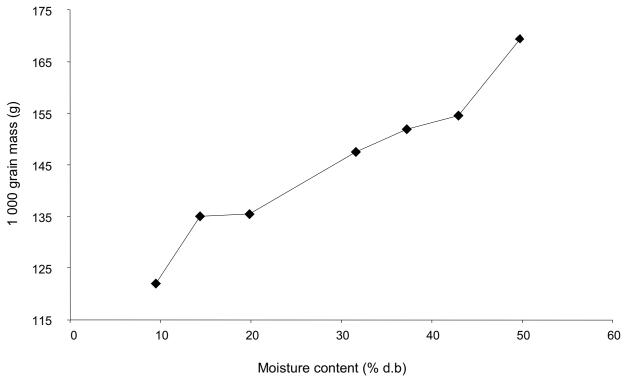

Fig. 4. Effect of moisture content on 1 000 grain mass of soybean.

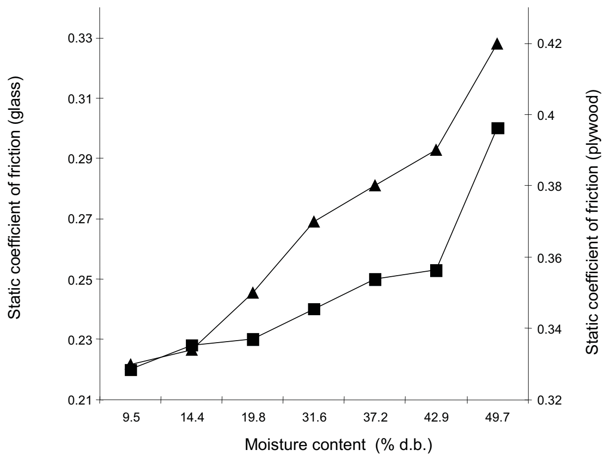

Fig. 5. Effect of moisture content on static coefficient of friction of soybean grains against two surfaces (glass and plywood), ■ – glass ◆ – plywood.

CONCLUSIONS

1. The average length, width, thickness, arithmetic and geometric mean diameter of grains ranged from: 6.53 to 7.96, 5.21 to 6.06, 4.28 to 4.94, 5.34 to 6.40, 5.26 to 6.18 mm, for the moisture content 9.5-49.7 % d.b.

2. The results of this research indicated that the angle of repose and coefficient of static friction for the two structural surfaces increased as the moisture content increased.

3. The bulk and true densities, porosity and sphericity decreased with increasing moisture content from 870.7 to 808.5, 1236.7 to 940.4 kg m^{-3}, 30 to 14% and 0.803 to 0.764%, respectively.

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