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PHYSICAL PROPERTIES OF SOYBEAN (*VAR* TGX 1019-2EB)

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ABSTRACT

Soybean (var TGX 1019-2EB) is one of the improved varieties that were developed by International Institute for Tropical Agriculture (IITA) , Ibadan a few years ago. This paper reports the effect of moisture content on the physical properties of the soybean cultivar.The average length, width, thickness and geometric mean diameter of the grain varied from 7.37 to 9.96, 6.48 to 7.45, 5.33 to 5.54 and 6.33 to 7.39 cm respectively as the moisture content varied from 6.7 to 47.1 % (db).One thousand grain mass varied from 130.67 to 180.21 g in the same moisture content range. The bulk density, seed density and sphericity decreased from 0.7285 to 0.6084 gmcm^{-3}, 1.1570 to 0.952 gmcm^{-3} and 0.860 to 0.749% respectively in the moisture content range .Porosity , surface area and volume of the grain increased from 0.2346 to 0.4233% ,1.262 to 1.715 cm^{2} and 0.145 to 0.195 cm^{3} respectively in the same moisture content range of 6.7 to 47.1%.The static coefficient of friction increased on three structural surfaces ,namely ,plywood parallel to grain (0.4877 to 0.6249), plywood perpendicular to grain (o.4922 to 0.6876) and galvanized steel (0.3839 to 0.5774) as the moisture content increased from 6.7 to 47.1%.Similarly the of angle of repose increased from 25.87 to 32.45 degrees in the same moisture content range. The above principal findings would be helpful in the design and development of handling, processing and storage equipment of this variety of soybean.

Keywords: Soybean (TGX 1019-2EB), Physical Properties, Moisture content, Models.

INTRODUCTION

Soybean is considered as one of the most important cereal grain in Nigeria. It contains about 40% protein and 20% cholesterol-free oil (Deshpande et al, 1993). Soybean oil is the world leading vegetable oil and accounts for about 20 to 24% of all fats and oil in the world. It is grown commercially in more than thirty-five countries of the world and the leading producer is the United States of America (about 45%) followed by Brazil (20%) and China (12%). In Nigeria,its production has been and is still concentrated in Benue and Kaduna states.Mineral content of soybean is about 1.7% for Potassium,0.3% for Magnesium,110 parts per million (ppm),50 ppm zinc and 20 ppm copper (Smith and Circle,1972).

In the last one decade, various improved varieties have been developed by the International Institute for Tropical Agriculture (IITA), Ibadan, Nigeria. Those varieties include TGX 1019-2EB, which is the object of this study. There are many other varieties which include TGX 1440-1E Manuwa (2000) and TGX 1148-2E Manuwa and Olofin (2003). The major improvements made on soybean varieties from 1987 through 1992 at IITA were to increase grain yield by about 20%, improve resistance to podshattering and to maintain the level of all other traits constant. To the best of our knowledge there is no indication that this work has been done or reported elsewhere.

In other to design equipment for handling, aeration, storing and processing soybean, its physical properties need to be known. The objective of this study was to investigate moisture – dependent physical properties of the grain, namely liner dimensions, geometric mean diameter, sphericity, surface area, volume, thousand grain mass, kernel density bulk density and porosity.

MATERIALS AND METHODS

Sample Preparation

Dry mature soybeans (glycine max . *CV* TGX 1019-2EB) were used for all the experiments in this study. The seeds were bred at IITA, processed and stored. They were bought in September, 1999 at a storage moisture content of about 10% (d.b). Before the experiments, the grains were further cleaned by removing those that were physically bad, unhealthy or broken.

The moisture content of the grain was determined using a standard method (USDA, 1970). Three samples each weighing about 20 g were placed in an oven, at 103 ^{0}C for 72 hours. The samples were then cooled in a desicator, reweighed and the moisture content of the grain calculated. Physical properties were determined at the initial moisture content. Thereafter, grain samples of higher moisture content levels were prepared by adding calculated amount of distilled water and sealed in separate polythene bags. The samples were kept at about 278 K in a refrigerator to redistribute uniformly throughout the sample.

Before commencement of a test, the required quantity of the grain was taken out of the refrigerator and allowed to warm up to room temperature at about 32^{0}C

Physical Properties

The physical properties to be determined are linear dimensions, surface, area, volume density, grain mass, coefficient of static friction on structural surfaces, and angle of repose. Experiments were conducted at seven moisture levels in the range of 6.7 to 47.1 (d.b) taking 10 replications at each moisture content. Average values are reported in this article.

Linear Dimensions and Geometric Mean Diameter

To determine the size of the grian, 10 subsamples each consisting of 100 grains were randomly taken. From each subsample, 10 grains were taken and their linear dimensions namely, length (L), width (W) and thickness (T) were measured with a venier calipers having accuracy of 0.01 mm. The geometric mean diameter (D_{GM}) of the grain was calculated by using the following relationship (Sree Narayanam *et al*, 1985; Sharma *et al*, 1985).

$$D_{GM} = (LWT)^{1/3} \quad (1)$$

Test Weight

One, one hundred and one thousand soybean grains from each sample were randomly selected and weighed on a digital electronic balance having an accuracy of 0.01g. The averages of the replicated values are reported.

Bulk and Seed Density

A method similar to that reported by Shepherd and Bhardwaj (1986) was used to determine the bulk density at each moisture level: a 180 ml cylinder was filled continuously from a height of about 15 cm. Tapping during filling was done to obtain uniform packing and to minimize the wall effect if any.The filled sample was weighed and bulk density of the material filling the sample was computed . This was also reported in Manuwa (2000). The seed density of the grain was determined by liquid displacement method to determine the seed volume, similar to that reported by Shephered and Bhardwaj (1986), Deshpande and Ali (1988).

Sphericity and Porosity

According to Mohsenin (1986), the sphericity, Φ, was calculated using the formula

$$\Phi = \frac{(LWT)^{1/3}}{L} \quad (2)$$

Fractional porosity is defined as the fraction of space in the bulk grain which is not occupied by grain. Thompsons and Isaacs (1967) gave the following relationship for fractional porosity.

$$E = \frac{(1 - \rho_b)}{\rho_s} \times 100 \quad (3)$$

where ε = fractional porosity

ρ_b = bulk density of the seed, g/cm^3

ρ_s = seed density, g/cm^3

Angle of Repose

The emptying angle of repose θ, was determined at seven moisture levels using the pipe method (Henderson and Perry, 1982; Jha, 1999; Manuwa, 2000). A pipe of 40 cm height and 106 mm internal diameter was kept on the floor vertically and filled with the sample. Tapping during filling was done to obtain uniform packing. The tube was slowly raised above the floor so that the whole material could slide and form a heap. The height above the floor H and the diameter of the heap D at its base were measured with a measuring scale and the angle of repose θ of the soybean computed using equation.

$$\theta = \text{Arctan}\,(2H/D) \quad (4)$$

Surface Area

The surface area of the grain was found by analogy with a sphere of geometric mean diameter for the different levels given by Mc Cabie *et al* (1986).

$$S = \pi D^2_{GM} \quad (5)$$

Coefficient of Static Friction

The coefficient of static friction for seed grain was determined against two structural surfaces namely plywood (with grain parallel to direction of motion and then perpendicular to direction of motion), galvanized steel (GS). A bottomless wooden box of 150 mm x 150 mm x 40 mm was constructed for this purpose. This was similar to that reported Oje (1994). The box was filled with soybean on an adjustable tilting surface. The surface was raised gradually using a screw device until the box started to slide down and the angle of inclination read on a graduated scale.

RESULTS AND DISCUSSION

Grain Dimension

The mean length, width, thickness and geometric mean diameter at a moisture content of 6.7% were 7.37, 6.48, 5.33 and 6.33 mm respectively. These dimensions were observed to increase with increase in moisture content (Fig. 1). From this figure it can be seen that as the moisture content of the grain increased from 6.7 to 4.71%, the length, width, thickness and geometric mean diameter increased to 9.96, 7.45, 5.54 and 7.31 mm respectively. In the moisture range, the length, width, thickness and geometric mean diameter increased by 35.14, 14.96, 3.93 and 16.47% respectively.

The relationship existing between the grain dimensions and moisture content was found to be linear and can be expressed by the following regression equations for length L, width W, thickness T and geometric mean diameter D_{GM}.

$$L = 7.158 + 0.055MC, (r^2 = 0.9804) \quad (6)$$
$$W = 6.324 + 0.022MC, (r^2 = 0.9706) \quad (7)$$
$$T = 5.283 + 0.005MC, (r^2 = 0.9787) \quad (8)$$
$$D_{GM} = 6.194 + 0.025MC, (r^2 = 0.9926) \quad (9)$$

where; MC is the grain moisture content. The increase of spatial dimensions with increase of moisture content was also observed by Deshpande et al (1993) for soybean (Js – 7244 variety), Ogut (1998) for white Lupin and Manuwa (2000) for soybean (TGX 1440 – 1E variety).

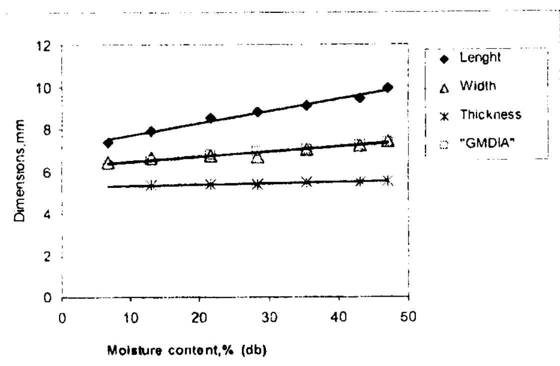

Fig. 1. Effect of moisture content on size of soybean TGX 1019 2EB

Grain Mass

The mean mass of 1 grain, 100 grains and 1000 grains ranged between 0.178 and 0.218, 13.782 and 18.798 and 130.668 and 180.210 respectively within the moisture content range of 6.7 to 47.1% db. The percentage increase in mass was observed to be 22.47, 36.39 and 37.91% respectively. The grain mass increased with increase in moisture content (Fig. 2). The following linear relationship was found to exist between the single grain mass M_1, one hundred grain mass M_{100} and one thousand grain mass M_{1000} and moisture content:

$M_1 = 0.172 + 0.0009MC, \quad (r^2 = 0.9804)$ (10)

$M_{100} = 12.945 + 0.120MC, \quad (r^2 = 0.9960)$ (11)

$M_{1000} = 122.675 + 1.188MC, \quad (r^2 = 0.9940)$ (12)

Similar trends were observed by Deshpande et al (1993) and Ogut (1998) for soybean and White Lupin, respectively.

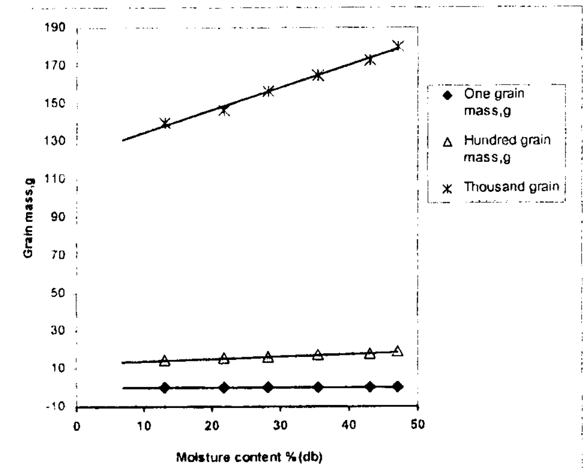

Fig. 2. Effect of moisture content on grain mass of soybean (TGX 1019-2EB)

Bulk Density and Seed Density

Bulk Density

The average bulk density of the grain was observed to decrease from 0.7258 Mg/m^3 to 0.6084 Mg/m^3 as the moisture content increased from 6.7 to 47.1% (Fig. 3). The decrease in bulk density with increase in moisture content was mainly due to the higher rate of increase in volume than mass. The bulk density of the grain was found to have the following linear relationship with moisture content.

$\rho_b = 0.742 - 0.0027MC, \quad (r^2 = 0.9860)$ (13)

The negative linear relationship was also observed by Deshpande et al (1993) for soybean, Ogut (1998) for White Lupin and Manuwa (2000) for soybean (TGX 1440 – 1E variety). The decrease in bulk density in this moisture range was 16.48%.

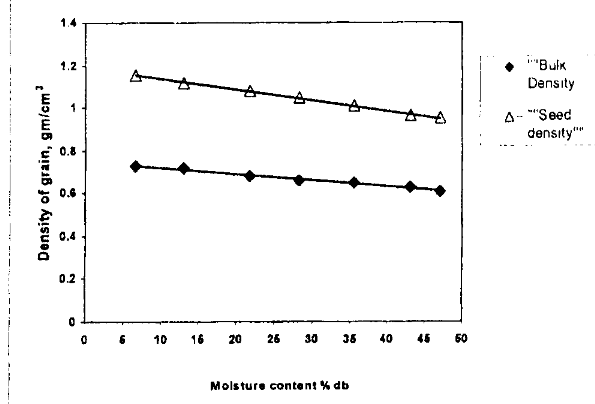

Fig.3. Effect of moisture content on density of soybean(TGX 1019-2EB)

Seed Density

The seed density was found to decrease from 1.1570 Mg/m^3 to 0.952 Mg/m^3 with an increase of moisture content from 6.7 to 47.1% d.b. A decrease of 20.05% in seed density was recorded for the seed in the moisture content range. The seed density was found to bear the following linear relationship with moisture content as shown in Fig 3.

$\rho_s = 1.199 - 0.0056MC, \quad (r^2 = 0.9868)$ (14)

The negative relationship was also observed by Shepherd and Bharadwaj (1986) for pigeon pea, Dutta et al (1993) for grain, Deshpande et al (1993) for soybean, Suthar and Das (1996) for Karingda Seed and Manuwa (2000) for soybean (TGX 1440 – 1E *cultivar*).

Sphericity

The shape of the grain in terms of sphericity was studied. Sphericity was found to decrease with increase in moisture content (Fig 4). In the moisture content range of 6.7 to 47.1% sphericity decreased by 12.9%. The linear relationship observed was given by:

$\Phi = 0.878 - 0.0026MC, \quad (r^2 = 0.9946)$ (15)

The decrease in sphericity with moisture content is probably due to the greatest expansion along its length rather than along its thickness. The negative relationship was also reported by Sahoo and Srivastava (2002) for okra seed at higher moisture content.

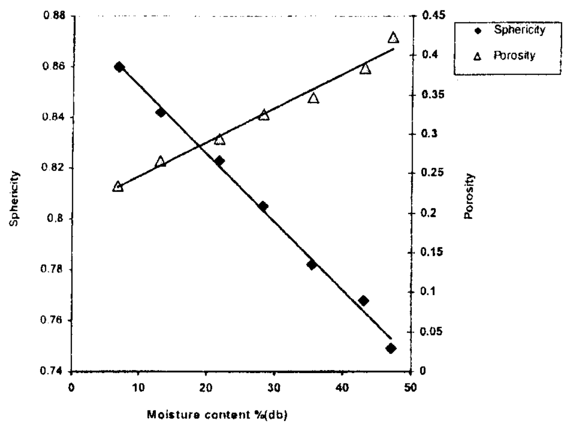

Fig. 4. Effect of moisture content on sphericity and porosity of soybean (TGX 1019-2EB)

Porosity

The porosity of the bulk increased from 0.2346 to 0.4233 when the moisture content increased from 6.7 to 47.1% d.b (Fig. 4). A similar trend was reported [Moshenin, 1986; Ogut and Sarman, 1991; Carman, 1996; Ogut, 1998; Aviara et al, 1999 and Manuwa, 2000]. The relation between porosity (ε) and moisture content for grain derived from the data is

$\varepsilon = 0.204 + 0.0043MC, (r^2 = 0.9826)$ (16)

Surface Area

The surface area of soybean grain increased from 1.262 to 1.715 cm^2, an increase of 25.89% in the moisture range of 6.7 to 47.1% d.b. (Fig.5). The following model was fitted to the data.

$S = 1.204 + 0.0107MC, (r^2 = 0.9414)$ (17)

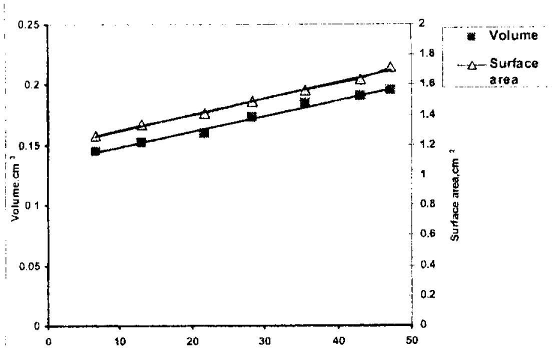

Fig. 5. Effect of moisture content on surface area and volume of soybean(TGX 1019-2EB).

Volume of Grain

The values of the volume of a single grain of soybean at different moisture levels varied from 0.145 to 0.195 cm^3 (Fig. 5) and indicated as an increase in grain volume with an increase in moisture content. The relationship between the grain volume and moisture content is given by

$V = 0.136 + 0.0012MC, (r^2 = 0.9866)$ (18)

A similar trend of linear relationship was observed by Dutta et al (1988) for grain.

Angle of Repose

The experimental result for angle of repose with respect to moisture content is shown in Fig. 6. It was observed that the angle of repose increased from 25.85 to 32.45^0 as the moisture content increased from 6.7 to 47.1% d.b. An increase of 25.33% in the angle of repose was recorded for soybean grain in the above moisture range and linear relationship was found to exist between the angle of repose, θ and moisture content and this can be represented by the following equation:

$\theta = 24.74 + 0.158MC, (r^2 = 0.9948)$ (19)

Increase in angle of repose was reported by Jha (1999) for Makhana Seed, Manuwa (2000) for soybean (var TGX 1440 – 1E) and Sahoo et al (2002) for okra seed.

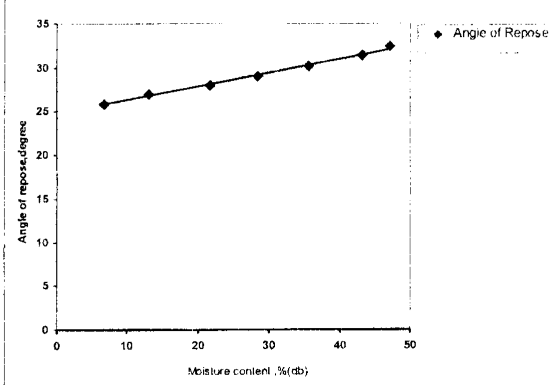

Fig. 6. Effect of moisture content on angle of repose of soybean (TGX 1019-2EB)

Coefficient of Static Friction

The plots of coefficient of static friction (on plywood parallel to grain, and perpendicular to grain and galvanized steel) against moisture content are presented in Fig.7). It was observed that the coefficient of static friction increased with increase in moisture content for all the surfaces. The coefficient of static friction increased from 0.4877 to 0.6249 for plywood parallel to grain, 0.4922 to 0.6876 for plywood perpendicular to grain and 0.3839 to 0.5774 for galvanized sheet as the grain moisture content increased from 6.7 to 47.1% d.b. The highest increase of 50.4% of coefficient of static fraction was recorded for galvanized steel within the same moisture range. The relationship between moisture content and coefficients of static friction on plywood parallel to grain μ_{swl}, plywood perpendicular to grain μ_{swd} and galvanized steel μ_{sgs} could be represented by the following equations.

$\mu_{swl} = 0.464 + 0.0032MC, (r^2 = 0.9934)$ (20)

$\mu_{swd} = 0.459 + 0.0046MC, (r^2 = 0.9936)$ (21)

$\mu_{sgs} = 0.3518 + 0.0045MC, (r^2 = 0.9940)$ (22)

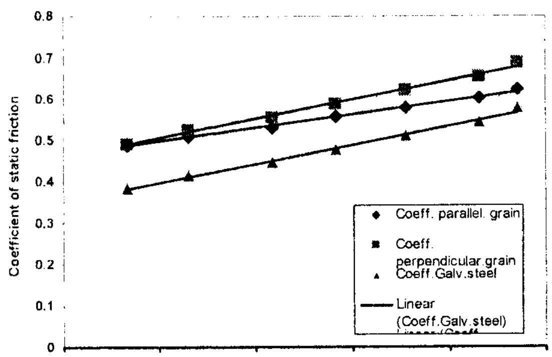

Fig. 7. Effect of moisture content on coefficient of static friction of soybean (TGX 1019-2EB)Moisture content %(db)

Oje (1994) reported increase in coefficient of friction for galvanized steel, plywood parallel to grain and plywood perpendicular to grain.

CONCLUSION

1. The average length, width, thickness and geometric mean diameter of soybean (Var. TGX 1019 – 2E) ranged from 7.37 to 9.96, 6.48 to 7.45, 5.33 to 5.44 and 6.33 to 7.39mm respectively as the moisture content increased from 6.7 to 47.1% d.b.
2. The soybean cultivar expanded more along its length in comparison with the other two principal axes with increase in moisture content.
3. Bulk density, seed density and sphericity decreased with increased moisture content.
4. The linear models developed in this study are very good for the prediction of the moisture – dependent properties within the moisture range, judging from their high coefficients of determination. The above stated conclusion provide information that are relevant in the design and development of processing and storage equipment of soybean variety (TGX 1019-2EB).

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