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Selected Physical Properties of Soybean In Relation To Storage Design

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ABSTRACT
Bulk density, kernel density, internal friction of Soybean were measured over a moisture content range of 7.4 to 22.22%(wb). First and second order polynomial equations are given which describe the kernel density, bulk density as well as other properties' dependence on moisture content. For the grain that was tested, bulk density, kernel density and specific gravity decreased with moisture content while angle of repose, angle of internal friction and coefficient of sliding friction increased as moisture content increased. One thousand grain weight and average diameter increased with moisture content for the crop. Frictional coefficients of the crop was measured on four structural surface namely: concrete, wood, galvanized sheet metal and mild steel sheet. The values were maximum for concrete among the four surfaces. The angle of repose was found to be higher than angle of internal friction in all cases tested. These measurements are necessary in selection of the material and in determination of pressures and angles of the wall of storage structures.
Key words- Bulk density, Kernel density, Specific gravity, Internal friction, Moisture content, Physical properties.

I. INTRODUCTION

Background Of The Study

Generally, physical properties of agricultural products are needed in design and adjustment of machines used during harvesting, separating, clearing, handling processing and storing of agricultural materials. The properties which are useful during design must be known and these properties must be determined with the appropriate cultivars. The grain storage structures are designed to have vertical walls for the primary storage volume and a conical bottom for effective material discharge. Different structural materials are used in constructing the silo walls. In some mechanized storage systems, the bottom is made flat while an unloading device is installed. In each case, most of the properties needed to predict the grain storage pressures are the physical and mechanical properties. The use of belt conveyors to convey granular agricultural solids along inclined paths in agro-industrial plant is fast gaining popularity. In such case, if the belt is inclined near the permissible angle of inclination, the materials may slip or fall back. The permissible angle at which there is no flow back of the materials is influenced by the coefficient of friction between the belt and the materials as well as the angles of repose and internal friction of the materials. In addition, the determination of the capacity of the belt conveyor requires that the bulk density of the grains be known.

Since most of these properties are influenced by other properties it is often desired to determine each property under a given set of conditions or states. Moisture content for instance, influences almost all grain properties, while specific gravity has been found to have a good correlation with moisture content and angle of repose of granular agricultural materials (Ezeike 1988). Information on values of these properties is at the moment grossly inadequate for our local grains. The result is that designers in agricultural engineering are made to make assumptions that may not be safe for designs.

There appears to be a very few published work on design-based properties of most Nigerian crops. These properties are needed to plan and design handling, processing and storage for these crops.

This work is aimed at experimentally determining the physical properties of grain in relation to storage designs. To be able to accomplish this project, the crop which is grown in Nigeria and is highly valued for its food and feed qualities was chosen. The selected crop is Soybean, *Glycine max.* (L.) Merril.

Soybean

(Glycine max L. Merril) belongs to the family leguminosae. It originated from east of Asia (Ogundipe, 2003). It ranked very high among the leguminous crops in the world in both protein content and general nutritional quality. It has different varieties varying in shape, color, size, physical properties and chemical composition (Wickel et al; 1979). It grows well in moderately sloppy soil, with moderate drainage.

The mature soybean seed has three major components; the seed coat (hull), the cotyledon and hypocotyledon constituting 8%, 90% and 2% of the seed respectively. The composition of soybean seed expressed as percent dry weight is presented in Table 1

Table 1 Composition of soybean and seed parts expressed as % dry weight.

Components	Yield	Protein	Oil	Ash	Carbohydrate
Whole soybean	100	40	21	4.9	34
Cotyledon	90	43	23	5.0	29
Hull	7.3	8	1	4.3	86
Hypocotyls	2.4	41	11	4.4	43

(Source: (Osho, 1988).

II. MATERIALS AND METHOD

Experimental Procedure

Angle Of Repose:

The equipment that was used for the determination of angle of repose is a box of 430mm long, 200mm wide and 430mm high. This equipment was used by Muir and Sinha, (1987) to determine the angle of repose of cereal and oil seed cultivars grown in western Canada. The angle of repose was measured by filling the box with the grain sample to depth of about 350mm and allowing it to flow out through a 50mm high rectangular opening along the bottom of the width.

The sloping profile of the grain after flow was determined using the geometry of the box and the profile.

The angle of repose (Ør) was calculated as follows;

Where, Ør = angle of repose in degrees

h = height of the grain profile at a distance

L = distance from the gate.

Bulk Density

This involves the use of hopper with top diameter of 225mm, a bottom diameter of 38mm and a height of 160mm for filling a 500ml container from a height of 45mm above the top of the container. A flat slide gate on the bottom of the hopper is used to control the flow of grains. The excess grain in the container is struck off with a straight edge and the mass of grain in the cup is measured. Bulk density was determined by dividing the mass of grain in the cup by the bulk volume.

Kernel Density:

The kernel density is determined by dividing the kernel mass by the volume found by fluid displacement. To find the volume of the grain kernels, the grains will be dropped in a graduated tube containing some water enough to cover the grains. The rise in the level of water in the tube is used to determine the volume of the grains since objects displace their own volume of fluid in which they are completely immersed. In this work, the grain density tube will be used with water as the fluid which the grains were smeared with light grease to avoid absorption of water.

Angle Of Internal Friction (Øi)

The direct shear test was used to determine the coefficient and angle of internal friction of the grains in this work. The material to be tested is put into the inner split shear box as shown in fig 12. The shear force is applied horizontally to the sample by a motor-driven push rod. The shear load applied to the sample is recorded by means of a proving-ring mounted on a horizontal plane. Deformation of the proving-ring monitored by a dial is related to the shear load applied by means of a calibration graph. As the shearing of the sample progresses records of time, proving-ring dial gauge and vertical deformation dial gauge are throughout the test until shear failure of the sample occurs. The point of failure is signified by a fall-off in recorded shear load for proving dial gauge with continued separation of the two halves of the shear box.

Sliding Friction (F_s)

The direct shear box apparatus is modified and used for determination of coefficient of sliding friction of grains. The surface to be tested is cut to the size of the split-shear box. By this, the shear surface coincided with surface of the test material as shown in fig. 13. The upper half of the box is filled with the grain to be tested on the surface in the lower half. Apart from these modifications, the procedure is the same as that of internal friction.

III. RESULTS AND DISCUSSION

TABLE 2: Mean values of angle of repose, bulk density, kernel density, angle of internal friction, specific gravity and moisture content of soybean

CROP	Moisture Content (% wb)	Angle of repose (deg)	Bulk density (kg/m^3)	Kernel density	Angle of internal friction (ØI)	Specific Gravity
Soybean	7.40	33.02	731.00	1266.10	17.6	1.1560
	13.00	34.00	712.00	1257.00	18.05	1.1548
	16.41	35.87	704.46	1186.37	23.80	1.1196
	21.10	38.07	670.00	1173.89	24.50	1.0968
	22.22	39.00	658.36	1159.74	26.05	1.0684

TABLE 3 Mean values of coefficient of sliding friction of soybean on various structural surfaces.

CROP	Moisture Content (%wb)	Concrete (Wood Floated)	Wood (Mahagany)	Galvanized Sheet Metal	Mildsteel Sheet
Soybean	7.4	0.252	0.158	0.134	0.201
	13.0	0.318	0.177	0.160	0.242
	18.6	0.321	0.190	0.163	0.254
	20.3	0.358	0.205	0.205	0.255

The experimental results for angle of repose are shown in Table 2. It was observed that angle of repose changed from 33° to 39° when the moisture content of soybean varied from 7.4 to 22.22%(wb); Analysis of variance showed that moisture content had a high significant effect on the angle of repose of the crop at 1% probability. The regression equation relating the angle of repose of the crop and its moisture content is shown as:

$Ør = 33.2 – 0.167Mc + 0.0193Mc^3$ (for soybean) – (1)

Coefficient of correlation R = 0.997

A multiple regression analysis by method of least squares for the best-fit to correlate the angle of repose of the crop and moisture content, bulk density and kernel density was

$Ør = 100 – 0.0764 – 0.0646p_b – 0.0231p_k$

(For soybean)

Coefficient of correlation r = 0.999

The plot of angle of repose versus moisture content is shown in Fig. 1

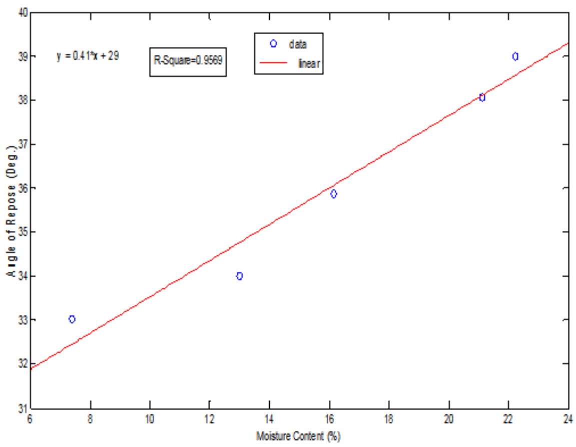

Figure 1: Angle of Repose of Soybean vs. Moisture Content

Bulk Density

The values of bulk density obtained experimentally are shown in Table 2. The moisture content increase resulted in decrease in the values of bulk density for the grain studied. The values of bulk density varied from 731 to 658.36kg/m^3 for soybean as the moisture varied from 7.4 to 22.22% wb. Fig 2 shows the plots of experimental values of bulk density versus moisture level of soybean. The bulk density of the grain was found to have the following relationships with moisture content:

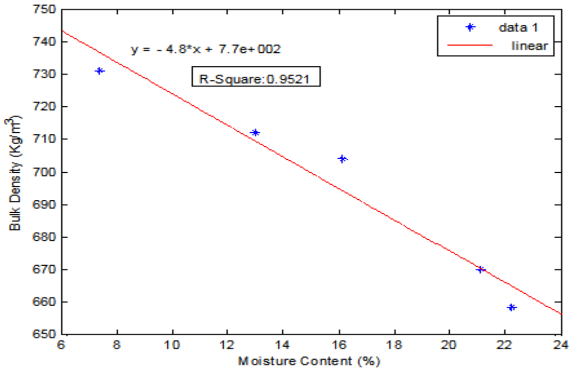

Figure 2: Bulk Density of Soya bean vs. Moisture Content

$\ell_b = -4.8Mc + 7.7e + 002$ (for soybean)……………………………………(2)

ℓ_b Correlation coefficient R = 0.9521

Kernel Density

Like bulk density, kernel density was found to vary inversely with moisture content of the grain.

For soybean it varied from 1266.10 to 1159.74 kg/m3 when the moisture varied from 7.4 to 22.22%(wb). Using least square method a polynomial for the best fit to correlate the grain kernel density and moisture content was obtained.

Specific Gravity

The specific gravity of the crop at their various moisture ranges are shown in table 2 for soybean. The moisture content ranges are 7.40 to 22.22% (wb) in that order. It was observed that determined values decreased with increase in moisture content in the range studied. The following equations give the relationship between the specific gravity and the moisture contents of the grain crop:

$S = -0.0032 Mc^3 + 0.24 Mc^2 - 5.2 Mc + 52$ (for soybean)………………………(3)

R = 1

The plot of specific gravity versus moisture content of the grain is shown in fig 3 below for soybean.

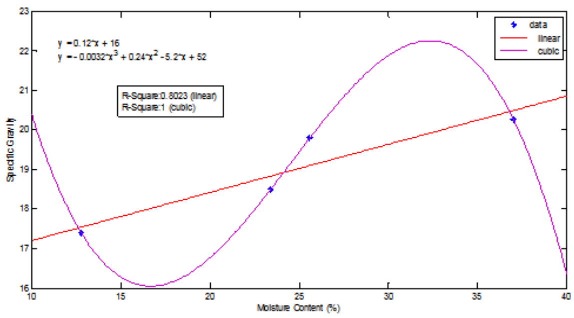

Figure 3: Specific Gravity of Soybean vs. Moisture Content

Coefficient of Sliding Friction

The experimental results showing the variation of coefficient of sliding friction of the grain on structural surface are shown in table 3. This (1) dynamic coefficient of friction was observed to increase as the moisture content increased for the crop on the four structural surfaces. (2)

Table 3 summarized the values of coefficient of sliding friction of soybean on wood, galvanized sheet metal and mild steel sheet. The regression equation for the crop on four surfaces are given below:

The bar chart of coefficient of sliding friction of the grain on the four structural surfaces are (4) shown in Fig. 4 for soybean.

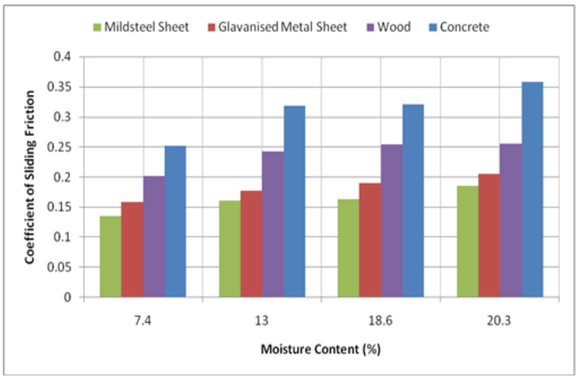

Figure 4: The bar chart of coefficient of sliding friction for Soybeans

Angle of Internal Friction

The values of the angle of internal friction of the grain crop tested in the experiment were observed to increase with moisture content as shown in table 2. The increase was observed for soybean. The analysis gave the following regression equation relating the angle of internal friction (Øi), moisture content (Mc) and angel of repose (Ør).

$\phi_i = 10.19 + 0.72\, Mc - 0.193 \tan\theta$ (for soya bean)…………………………..(4)

The plot of angle of internal friction versus moisture content is shown in fig. 5 for soybean.

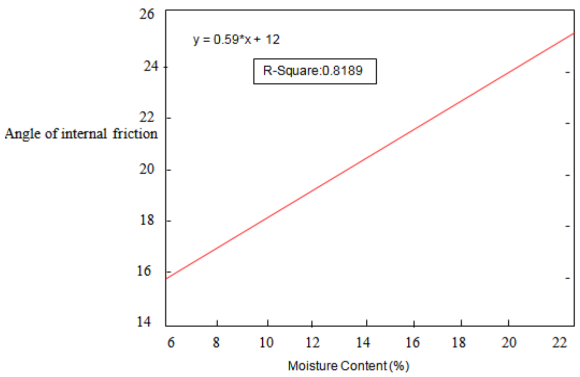

Figure 5: Angle of Internal Friction of Soya bean vs. Moisture Content

IV. CONCLUSION

This experimental investigations of various properties of the grain revealed the following:
The bulk density and kernel density decrease with moisture content over the moisture range from 7.4 to 22.22% for soybean.
The specific gravity decreased with moisture content for the moisture range from 7.4 to 22.22% for soybean.
(3) The dynamic angle of repose (emptying) increases with increase in moisture content of the grain for moisture range of 7.4 to 22.22% (wb) for soybean.
The angle of internal friction has a high correlation with moisture content but differs from angle of repose for the grain studied. The values of internal friction are lower than the values of angle of repose as can be seen in previous figures.
The dynamic coefficients of sliding friction of soybean increases with moisture content and significantly differs from surface to surface for the four surfaces studied. Among concrete, wood, galvanized sheet metal, and mild steel sheet, the values of the coefficient of sliding friction are maximum with respect to concrete.
The values determined in this work compare favorably well with those reported in literature.

RECOMMENDATION

More research is needed in the area of physical properties of our local agricultural products under our local conditions. This is the only way to generate data that will be appropriate to our indigenous designs. Design and development of devices to study these properties should be embarked on as a matter of urgency, since the modification of the imported ones for our local crops often introduces errors that could be mistaken for treatment effects.

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