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Research Paper :

Study of moisture based physical properties of soybean

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ABSTRACT

Some moisture based physical properties of soybean were determined in order to facilitate the design of processing equipments. In this study some of the physical properties of soybean such as grain size, sphericity, grain volume, thousand grain weight, true density, bulk density, bulk porosity, angle of repose, and static coefficient of friction were evaluated as a function of moisture content in the range of 7.37, 10.92, and 15.80 %. The grain size increased from 5.441 to 5.571 mm, grain volume increased linearly from 80 to 83.72 mm^3, whereas sphericity increased from 0.8329 to 0.8415 due to change in moisture content from 7.37 to 15.80 % (db). The bulk density and true density were decreased from 749.1 to 644.4 kg/m^3 and 1250 to 1111.11 kg/m^3, respectively, while the bulk porosity was increased from 40.07 to 41.9 per cent in the specified moisture content. The angle of repose and thousand grain weight increased from 26.35 to 30.96 degree and 103.57 to 109.57 g, respectively as moisture content increased from 7.37 to 15.80%. The static coefficient of friction increased linearly against all the tested surfaces as moisture content increased.

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Soybean (*Glycine max.*) is an important annual plant. The requirements for soybean used directly or indirectly for human consumption increases with population increase. It is estimated that soybean production in world is about 180 million tons per year. For the past several decades, production of soybean has steady increase in India. Soybean production in India has increased to 4.89 million tones. About 80% soybean production in India is in the State of Madhya Pradesh alone. The other states which grow significant amount of soybean are Maharashtra, Rajasthan, and Uttar Pradesh.

Soybean produces 2-3 times more protein per hectare than any other legume / pulse. It contains 40% protein, 23% carbohydrates, 20% cholesterol – free oil and reasonable amount of mineral and vitamins. It is chief constituent of soy-milk and also panir which makes a delicious milk product. In order to design equipment for handling, aeration, storing and processing of soybean its physical properties need to be known. Designing of such equipments and machines without taking these into considerations may yield poor results. The objective of this study was to investigate effect of moisture content on physical properties of the soybean, namely, physical dimension, size, sphericity, bulk density, thousand grains mass, true density, bulk porosity, angle of repose, grain volume, static coefficient of friction. This information about physical properties of soybean is valuable not only to engineer's but also to food scientists and processors and plant breeders.

METHODOLOGY

Preparation of grain samples:

The test sample of soybean was sun dried in order to reduce the moisture content and the corresponding moisture content was 6.70-7.90 % (db). Sun dried samples were moistened with a calculated quantity of water by using equation 1 and conditioned to raise their moisture content to the desired two different levels. A predetermined quantity of tap water was added to the grain lot of 3 kg and was thoroughly mixed. These rewetted grain lots were sealed in high molecular high density poly ethylene bags, which were kept inside wet gunny bags for 24 hrs at room temperature.

$$W_1 (100 + M_2) = W_2 (100 + M_1) \quad \ldots. (1)$$

where,

W_1 and W_2 = Initial and final weight of the sample, g and

M_1 and M_2 = Initial and final moisture content of the sample, % (db)

Physical properties:

Physical properties namely grain dimensions, sphericity, grain size, grain volume, thousand grain mass, bulk density, true density, bulk porosity, angle of repose, and static coefficient of friction of the soybean was studied at various moisture content and average of three replications have been calculated. Moisture content of grain sample of known weight (about 25g) was determined by following a standard oven drying method at an air temperature of 105 ± 2^0C for 24 hrs before taking the final weight. Average of three replications was noted and reported as moisture content of the sample.

Grain size:

The geometric mean diameter was considered as the size criterion. It is the cube root of product of three axes of the grain. Three major principle axis of the grain were measured with the help of vernier caliper having a least count 0.01 cm. Three treatments were taken for each moisture content and average value was calculated from 100 randomly selected sound grains for each sample. Therefore, the total 300 readings were calculated for each moisture content.

$$\text{Size} = (\text{length} \times \text{width} \times \text{thickness})^{1/3} \quad \text{.....(2)}$$

Sphericity:

Degree of sphericity can be expressed as follows

$$\text{Sphericity}, \Phi = \frac{\text{Geometric mean diameter}}{\text{Major diameter}}$$

$$i.e. \quad \Phi = \frac{(ABC)^{\frac{1}{3}}}{A} \quad \text{..... (3)}$$

where,

A, B, C are principle axes of major, medium, and minor respectively of the grain.

Grain volume:

Grain volume was determined by toluene displacement method. Grain sample of about 5 g was dipped into the toluene. The volume displaced by the grains was noted. The true volume of grains was divided by the number of grains to find the grain volume.

Thousand grains mass:

A method as suggested in IS-4333 (Part IV) - 1968 was used to determine thousand grain mass. One thousand randomly selected sound grains of soybean were collected and weighted on an electronic top pan balance for different moisture levels. Average of three replications have been considered and reported as thousand grains mass.

Bulk density:

Bulk density of the grain is the ratio of its mass to bulk volume of sample. It was determined by filling a 1000 ml container with kernels from the height of about 15 cm, striking the top level and then weighing the content.

True density:

The ratio of mass of the sample to the true volume is termed as true density of the sample. It was determined with toluene displacement method. Grain sample (about 5 g) was submerged in toluene in a measuring cylinder having an accuracy of 0.1 ml; the increase in volume due to sample was noted as true volume of sample which was then used to determine the true density of the sample.

Bulk porosity:

It is the percentage of volume of voids in the test sample at given moisture content. It was calculated as the ratio of the difference in the true density and bulk density to the true density volume and expressed in percentage from the following equation.

$$\varepsilon' = \frac{\rho t - \rho b}{\rho t} \times 100 \quad \text{..... (4)}$$

where,

ε = Porosity, %

ρ_t = True density, kg/m^3

ρ_b = Bulk density, kg/m^3

Experimentally determined true density and bulk density values of the cereal grain samples as different moisture contents were utilized to determine the bulk porosity values.

Angle of repose:

When granular material is allowed flow freely from a point into a pile, the angle which the side of pile makes with a horizontal plane is called angle of repose. For measuring the angle of repose a cylindrical cone method was used, having dimensions 9 cm in height and 5 cm internal diameter. The cone filled with grain was placed on the floor and the discharge quickly allowing the grains to slide down and assume their natural slope the angle of repose was calculated by using the following formula:

$$\varepsilon = \tan^{-1}(2h/d) \quad \text{.. (5)}$$

where,

ε = Angle of repose in degree

h = Height of pile, mm
d = diameter of disc, mm

Static coefficient of friction:

The ratio between the force of friction and the force normal to the surface of contact is termed as static coefficient of friction. Coefficient of friction is also given by the tangent of the angle of the inclined surface upon which the friction force tangential to the surface and the component of the weight normal to the surface are acting. The static coefficients of friction of soybean grains were determined on two different materials, namely, glass and wood. The tilting platform of 350 x 120 mm was fabricated and used for experimentation. A topless and bottomless plastic box of dimensions 45 mm x 45 mm x 100 mm was filled with grain and placed on the adjusted tilting surface. The box was raised slightly so as not to touch the surface. The structural surface with the box resting on it was inclined gradually with a screw device until box just started to slide down and the angle of tilt was read from a graduated scale.

RESULTS AND DISCUSSION

The results of the present study as well as relevant discussion have been summarized under following heads:

Physical properties:

Grain size, sphericity, and grain volume measurement:

The experimental data obtained for grain size, sphericity, and grain volume of soybean grains at different moisture content are given in Table 1.

The grain size, sphericity, and grain volume were found to increase from 5.44 mm to 5.57 mm, 0.8324 to 0.8415, and 80 mm^3 to 83.72 mm^3, respectively as moisture content increased from 7.37 to 15.80 % (db). Result showed that grain size, sphericity, and grain volume increased linearly with moisture content.

Thousand grain weight:

Experimental data obtained for thousand grain weight of soybean are given in Table 2. The thousand grain weight increased linearly with increase in moisture content. The value of thousand grain weight increased from 103.57 to 109.67 g as moisture content increased from 7.37 to 15.80 % (db) and the per cent increase in thousand grain weight was 5.86 per cent.

Bulk density, true density and porosity measurement:

The bulk density of soybean decreased from 749.1 to 644.4 kg/m^3, as moisture content increased from 7.37 to 15.80 % (db). The true density of soybean was found to decrease from 1250 kg/m^3 at a moisture content of 7.37 % to 1111.11 kg/m^3 at moisture content of 15.80 % (Table 2). The porosity of soybean at different moisture content was found to increase from 40.07 to 41.9 % with increase in moisture content from 7.37 to 15.80 % (db).

Angle of repose:

The experimental data obtained for angle of repose of soybean was given in Table 2. The angle of repose increased linearly with increase in moisture content. The value of angle of repose increased from 26.35 to 30.96 degree as moisture content increased from 7.37 to 15.80 % (db). The per cent increase in angle of repose was 17.49 per cent.

Static coefficient of friction:

At all moisture contents, the static coefficient of friction was the highest for soybean against wood and least for glass. As the moisture content of soybean increased, the static coefficient of friction increased linearly. At 7.37 % (db) moisture content static coefficient

Table 1: Principle dimensions, grain size, sphericity and grain volume of soybean

Moisture content (%) (db)	Major axis (mm)	Medium axis (mm)	Minor axis (mm)	Grain size (mm)	Sphericity	Grain volume (mm^3)
7.37	6.55	5.56	4.53	5.44	0.8324	80
10.92	6.66	5.60	4.56	5.53	0.8339	80.95
15.80	6.73	5.64	4.64	5.57	0.8415	83.72

Table 2 : Thousand grain weight, bulk density, true density and angle of repose of soybean

Moisture content (%) (db)	Thousand grain weight (g)	Bulk density (kg/m^3)	True density (kg/m^3)	Bulk porosity (%)	Angle of repose (degree)
7.37	103.57	749.1	1250	40.07	26.35
10.92	104.87	700	1176.47	40.49	27.89
15.80	109.67	644.4	1111.11	41.90	30.96

Table 3 : Values of static coefficient of friction for soybean against different surfaces

Moisture content (%) (db)	Glass	Wood
7.37	0.53	0.70
10.92	0.55	0.72
15.80	0.57	0.78

of friction of soybean was 0.70 on wood, 0.53 on glass (Table 3). Similar type of works have been conducted in past by Deshpande *et al.* (1993), Maudhyan and Prasad (1994), Unde and More (1996) and Polat *et al.* (2006).

Conclusion:

The various properties of soybean measured will serve as a useful tool in process and equipment design and this will go in a long way in assisting to improve yield and quality of soybean. The following conclusions were drawn from this investigation into the properties of soybean.

– All the physical properties of soybean to be dependent on their moisture contents.

– At the moisture content of 7.37 % (db), the average length, width, and thickness of soybean were 6.55, 5.56, and 4.53 mm, respectively, while the corresponding values at the moisture content of 15.80 % (db) were 6.73, 5.64, and 4.64 mm.

– At the moisture content of 7.37 and 15.80 % (db) the average thousand grain weight of soybean was 103.57 and 109.67 gm, respectively.

– Grain size, sphericity, and grain volume increased with increase in moisture content.

– As the moisture content increased from 7.37 to 15.80 % (db) bulk density and true density decreased from 749.1 to 644.4 kg/m^3 and 1250 to 1111.11 kg/m^3, respectively. Bulk porosity increased with increase in moisture content.

– Angle of repose increased from 26.35 to 30.96 degree as moisture content increased from 7.37 to 15.80 % (db).

– Static coefficient of friction of soybean was found higher for wood than glass and it is increased with increasing moisture content.

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