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Evaluating the effects of some relevant parameters on physical properties of sunflower seed

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ABSTRACT: Some of the physical properties of sunflower included shape and size, unit mass, densities, and angle of repose were studied in experimental condition for its significance with respect to some relevant parameters for having basic data to design the sunflower dehuller. Some of the physical properties like spatial dimensions, porosity, true density and angle of repose increased with increase in moisture content. However some of the physical properties like bulk density and sphericity decrease with increase in moisture content.

Key Words: Bulk density, true density, sphericity, thousand grain weight and angle of repose.

The physical, mechanical, frictional, rheological and engineering properties of any grain play an important role for designing any processing machine. Physical properties included shape and size, unit mass, densities, shape and size are important parameters, which govern design of different machines like winnowers, cleaners and graders. Knowledge of density, specific gravity and porosity are important in design and analysis of separation, handling, drying, processing, storage and transportation equipment and system. Bulk density gives the capacity of storage structure. Specific gravity is a widely criteria of separation of food material. Porosity of solid mass governs the resistance to airflow in a dryer and dictates the thickness of the layers, which can be dried safely and the type of blower needed. The angle of repose is important in designing equipment for solid flow and structure for storage of the material.

In most of biological materials, the geometric characteristics, density and mechanical properties of are dependent on moisture content. Many researchers have studied these moisture-dependent properties for various biological materials. Amin *et al.* (2003) reported the frictional properties and terminal velocity of two common types of garlic cloves (white and pink) in Iran and Jayan and Kumar (2004) evaluated the physical properties of maize, red gram and cotton seeds. Some physical properties of fenugreek seeds were evaluated by Altuntas *et al.* (2005) where as Asoegwu *et al*. (2006) measured some physical properties of African oil bean seeds. Seyed and Milani (2006) selected watermelon seeds of three major local Iranian varieties to study the physical properties. Eke *et al.* (2007) and Kiani *et al*. (2008) investigated engineering properties of Jack-bean and red bean respectively where as Zewdu and Solomon (2007) and Nihat *et al*. (2007) studied moisture-dependent physical properties under the experimental condition of Tef and Gilaburu seed. Bamgboye and Adejumo. (2009) and Davies (2009) determined the physical properties of Roselle and groundnut respectively. Razavi *et al.* (2009) reported the physical properties of four common Iranian varieties of canola seeds. Seyed Mohammad *et al.* (2011) evaluated the physical properties of castor seed for designing the equipment for processing, sorting and sizing. Figueiredo *et al.* (2011) carried out the moisture-dependent engineering properties of safflower seeds with different structural characteristics. Kara *et al.* (2012) investigated two safflower cultivars namely Remzibey-05 and Dinçer in order to determine their frictional and aerodynamic properties as a function of moisture content.

However, few reports related to physical properties on some verities of sunflower are available. Gupta and Das (1997) observed the physical properties of sunflower seeds. Herna´ndez and Belle´s (2007) studied the finite element analysis of the sunflower (*Helianthus annuus* L.) fruit with respect to the biomechanical approach for the improvement of its hullability. Khodabakhshian *et al.* (2012) observed the effect of variety, size and moisture content of sunflower seed and its kernel on their terminal velocity, drag coefficient, and Reynolds's number.

The aim of this study was to determine some physical properties of sunflower seeds that are often required to develop equipment for handling, storage, transportation, drying, and other processes involving the seed.

Materials and Methods

Raw materials and sample preparation

The early duration **Pioneer** variety of sunflower (*Helianthus annus* L.) was selected for this study and good (sound) quality of seed was procured from the market. The seed were properly cleaned and graded to remove the impurities and undersize seed-grains by using appropriate set of sieves to remove foreign matter, broken and immature seed. The cleaning was done by cleaner with upper and lower screen of 5.5 mm and of 2.0 mm oblong hole respectively and followed by grading of cleaned seed into three categories, namely large (L>11mm), medium (8<L>10mm) and small (L<8mm) using ASTM sorting sieves. This operation was performed to get the seed of uniform size.

Moisture content determination

Moisture content of the sample was determined by using standard hot air electric oven drying method, which was recommended by International Seed Testing Association ISTA (1995) at 105±5°C for 24h for oilseed. The moisture content has been expressed as percentage dry weight basis. Five gram weight of each sample size was taken and transferred to a pre-dried and cooled Petridis weight M_1, on electronic balance (capacity 500g, least count 0.001g) and wt. of dish + sample (M_2) to be used. Dish containing sample was quickly placed in the oven at 105°C±5°C and dried for 24 hours. The drying period was to be considered to begin at the time oven attained the required temp. After the period of 24 hours, dish was quickly taken out from oven and kept in desiccators having moisture free silica-gel for cooling to an ambient temperature. When the dish was cooled to room temperature (took 30-45 minutes), the weight (M_3) was measured. The moisture content determinations were replicated thrice. Mean values of 3 replications were reported. Moisture content was calculated by the following formula

$$X_d = \frac{M_2 - M_3}{M_3 - M_1} \times 100$$

Where,

X_d = Moisture content % (d.b.)

M_1 = Weight of dish, g

M_{12} = Weight of dish + sample before drying, g

M_3 = Weight of dish + sample after drying, g

Moisture conditioning of seeds

To study the effect of moisture content on the physical properties of the seed, samples of seed of required moisture contents were prepared by adding distilled water and sealing in separate polyethylene bags.

The sample size of seed was taken 500g. The moisture content level of sunflower oilseed was adjusted and conditioned to 5.41%, 9.13%, 13.15%, 1719.14% (d.b) by adding predetermined quantity of water as per the formula given below and periodically by stirring in the air tight plastic bags.

$$Q_w = \frac{MC_r}{100 - MC_r} W_d - W_m$$

Where,

Q_w = Quantity of water to be added, gm

MC_r = Required moisture content % w.b

W_d = Weight of the dry material, gm

W_m = Weight of initial moisture content, gm

The sample was kept at low temperature (278°K) in a refrigerator for uniform moisture distribution and to retard the growth of microorganisms. Before starting a test, the required quantity of the sample was taken out and was allowed to retain the room temperature (Joshi *et al.,* 1993). Such a wetting technique to obtain the desired moisture content in the seed and grain has been used by many researchers (Brusewitz, 1975; Shepherd and Bhardwaj, 1986; Dutta *et al.*, 1988; Joshi *et al.*, 1993).

Measurement of length, width and thickness

The length (L), width (W) and thickness (T) of sunflower seed was measured with the help of screw gauge Mitutoya (micrometer) having least count (0.001mm). Seed was selected randomly from the sample to measure the length (L), width (W) and thickness (T) and the sample size was taken as 30.

Determination of bulk density and true density

The bulk and true for both seed at different moisture levels were determined. The bulk density is the ratio of the mass sample of the grain to its total volume. It was determined by filling 1000 ml and 500ml of measuring cylinder with the seed grains at height of 15 cm striking the top level and then weighing the contents (ISI, 1967). For 1000 ml of measuring cylinder height was taken between (700-800) ml and for 500 ml height was taken between (400-450) ml in the cylinder. The filled seed grain was weighted. The bulk density was determined with the help of following formula —

$$\text{Bulk Density}\left(\frac{\text{g}}{\text{cm}^3}\right) = \frac{\text{Weight of seed grain}}{\text{Volume of the measuring cylinder (cm}^3\text{)}}$$

Average values of all different replications were reported as the Bulk Density of seed grains.

The true density is defined as the ratio of mass of the sample to its true volume (Joshi *et al.*, 1993) and it was determined by using an electronic balance and air comparison pycnometer. Thompson and Isaac (1967) defined porosity (Pf) as that fraction of the space in the bulk grain which is not occupied by the grain. The percentage was calculated from the following relationship (Mohsenin, 1980). The True density was determined by using petroleum ether. In a volumetric cylinder known volume of petroleum ether was taken. A known weight of seed grains was placed in cylinder. The rise in the

Table-1 : Spatial dimensions of sunflower seeds with varying moisture content (%, db).

S. No.	Moisture Content, % db	Length, mm	Width, mm	Thickness, mm
1	5.41	11.45±0.45[a]	6.13±0.51[a]	4.23±0.42[a]
2	9.13	11.58±0.54[a]	6.27±0.63[a]	4.32±0.49[a]
3	13.15	12.12±0.58[b]	6.57±0.42[b]	4.38±0.43[a]
4	17.14	12.17±0.56[b]	6.64±0.44[b]	4.39±0.31[a]

Figures in a column followed with different superscripts are significantly different ($p<0.05$)

vol. of petroleum ether was measured in the cylinder. By using the following formulae, true density was calculated as:

True Density (g/cm^3)

$$= \frac{\text{Weight of seed grain (g)}}{\text{Rise in volume of the measuring cylinder (cm}^3\text{)}}$$

A 500 ml capacity-measuring cylinder was taken; up to 150 ml the cylinder was filled with petroleum ether. The known weight of seed grains (50g, 75g, 100g) was placed into the cylinder, and then rise in the volume of petroleum ether was recorded. Average values of all different replications were reported as the True density of seed grains.

Determination of sphericity

The seed shape was determined in term of their sphericity. The sphericity (ϕ_f) of the seed grains is calculated by using the following formulae (Mohsenin, 1980).

$$\varphi_s = \frac{(LWT)^{1/3}}{L} \times 100$$

Where,

L = Length (mm)

W = Width (mm)

T = Thickness (mm)

Thousand grain weight

Thousand grain's weight was determined using the method described in Indian Standard IS: 4333 (Part IV) – 1968. The method is as follows

Determination on 'As – is' basis

500 representative number of whole grains were taken from the test material and weighed

The weight of 1,000 grains of 'as – is' basis

$$= \frac{a \times 1{,}000}{b}$$

Where,

a = weight of the whole grains, g and

b = Number of whole grains in the sample weighed.

Porosity

The per cent voids of an unconsolidated mass of materials in terms of volume can be defined as porosity

$$\text{Porosity} = \frac{\text{(True density - Bulk density)}}{\text{True density}}$$

Angle of repose

To determine the angle of repose, a plywood box of 0.30m x 0.30m with a removable front panel was filled with grains. The front panel was quickly removed allowing the seed to flow and assume a natural slope. The angle of repose was calculated from the measurements of the vertical depth and radius of spread of the sample (Shepherd and Bhardwaj, 1986; Joshi *et al.*, 1993). Three replications were made at each levels of moisture content. To obtain the angle of repose (θ_f) for filling samples were from a certain height on a wooden horizontal surface. The height of pile above the floor (H) along with the diameter of the heap (D) was measured and following relationship was used to determine the angle of repose (θ_f) for filled sample of sunflower:

$$\theta_f = \tan^{-1}\left(\frac{2H}{D}\right)$$

H = Height of pile above the floor

D = Diameter of the heap

θ_f = Angle of repose for filled sample

Result and Discussion

Spatial Dimensions (length, width, thickness)

Effect of moisture content on special dimensions of sunflower seeds (Variety: Pioneer) is reported in Table-1

The seed length increased linearly from 11.45 mm to 12.17 mm with increase in moisture content from 5.41% to 17.14% (db). The increase in length was significant when moisture content increased from 5.41% to 17.14%. However increase in length was not significant with increase in moisture content from 5.41% to 9.13%. Similar trend has been reported by Figueiredo *et al.* (2006) *and* Gupta and Das (2000) for sunflower seeds.

The change in length of sunflower seeds can be represented by the following equation.

$$L = 0.07M + 11.06 \qquad (R^2 = 0.89)$$

The width of seed increased linearly from 6.13 mm to 6.64 mm with increase in moisture content from 5.41% to 17.14% (Table-1). Increase in width of seed was not significant with increase in moisture content from 5.41% to 9.13%. However, the increase in width was significant when moisture content increased from 5.41% to 13.15%. Similar trend of increase in width of sunflower seed has been reported by Figueiredo *et al.* (2006) and Gupta and Das (2000). The change in width of sunflower seeds can be represented by the equation.

$$W = 0.04M + 5.97 \qquad (R^2 = 0.93)$$

The thickness of sunflower seeds increased from 4.23 mm to 4.39 mm with increase in moisture content from 5.41% to 17.14% (Table 1). Increase in thickness of seed was not significant with increase in moisture content range under study. Significant increase in sunflower seed thickness was reported by Gupta and Das (2000), whereas Figueiredo *et al*. (2006) reported non-significant increase in seed thickness. The change in thickness of sunflower seeds can be represented by the following equation.

$$T = 0.01M + 4.25 \qquad (R^2 = 0.91)$$

Sphericity

The effect of moisture content on sphericity (f) of sunflower seeds is shown in Fig.-1. Sphericity of sunflower seeds decreased slightly from 0.59 to 0.58 with moisture content. However, the decrease in sphericity was not significant ($p>0.05$). The length, width and thickness of seeds increased with moisture content and change in thickness was not significant. This resulted in slight decrease in f of sunflower seeds. The effect of moisture content on f of sunflower seeds can be represented by following expression.

$$\phi = 0.59 - 0.001M \qquad (R^2 = 0.79)$$

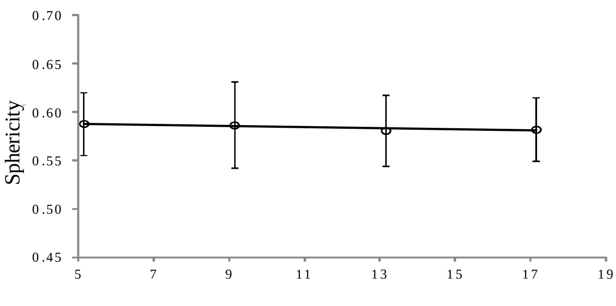

Fig.-1: Effect of moisture content on sphericity of sunflower seeds.

Geometric mean diameter

The effect of moisture content on geometric mean diameter (D_g) of sunflower seeds is reported in Fig.-2. Geometric mean diameter of sunflower seeds increased slightly from 6.73 to 7.02 mm with moisture content. However, the increase in D_g was not significant ($p>0.05$) in the moisture content range under study. The geometrical dimensions of seeds increased with moisture content whereas change in thickness was not significant. This resulted in slight increase in D_g of sunflower seeds. The increase in D_g of sunflower seeds was linear. The value of D_g for sunflower seeds was in the range reported in literature. The effect of moisture content on D_g of sunflower seeds can be represented by equation.

$$D_g = 6.55 + 0.031M \qquad (R^2 = 0.91)$$

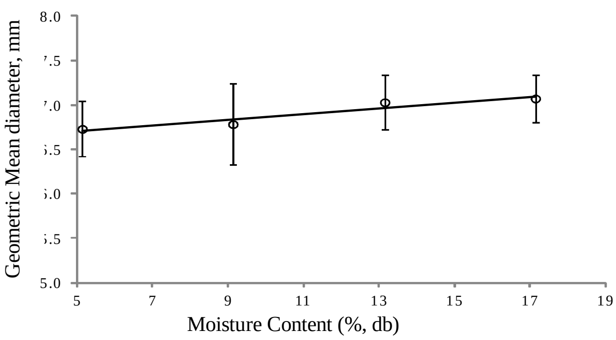

Fig.-2: Effect of moisture content on geometric mean diameter of sunflower seeds.

Bulk Density

The variation of bulk density of sunflower seeds with moisture content is presented in Fig.-3. The bulk density decreased linearly from 323.43 kg/m^3 to 310.15 kg/m^3 with moisture content. The decrease in bulk density with moisture content was significant ($p<0.05$; Table-2). The increase in moisture content resulted decrease in sphericity and thus the pore spaces might have increased more than the increase in seed volume. It indicated that sunflower seeds would require more space while storage at higher moisture contents. Similar trend of decrease in bulk density of sunflower seeds has been reported by Figueiredo *et al.* (2006) and Gupta and Das (2000). The relationship between moisture content and bulk density was expressed by Equation.

$$\rho_b = 329.57 - 1.13M \qquad (R^2 = 0.99)$$

Table-2: Test of significance of bulk density.

T-test for Dependent Samples Marked differences are significant at $p < .05000$ for bulk density of sunflower

	Mean	Std.Dv.	N	Diff.	Std.Dv.	t	df	p
MC	11.20	4.44						
BD	316.91	5.30	40	-305.71	9.61	-201.15	39	0.00

Table-3: Test of significance of true density of sunflower seeds.

T-test for Dependent Samples Marked differences are significant at $p < .05000$ for true density

	Mean	Std.Dv.	N	Diff.	Std.Dv.	t	df	p
MC	11.20	4.47						
TD	767.86	10.34	24	-756.66	6.15	-601.78	23	0.00

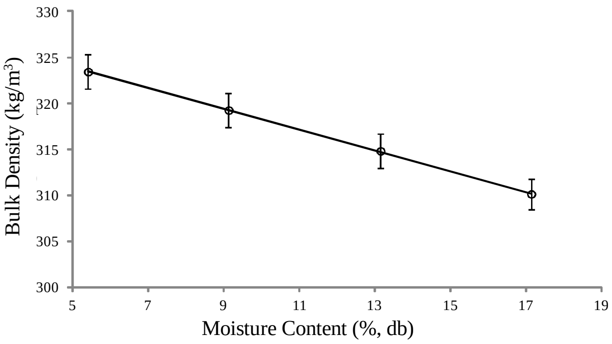

Fig.-3: Effect of moisture content on bulk density of sunflower seeds.

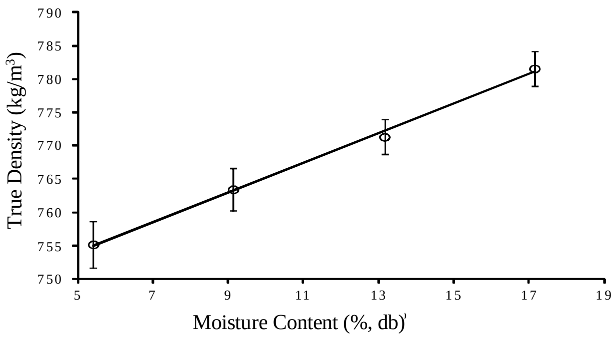

Fig.-4: Effect of moisture content on true density of sunflower seeds.

True Density

The variation of true density of sunflower seeds with moisture content is presented in Fig.-4. Test of significance of true density of sunflower seeds is listed in Table-3. The true density increased linearly from 755.17 kg/m^3 to 781.57 kg/m^3 with moisture content. The increase in moisture content resulted less increase in seed volume in comparison to weight gain due to absorption of water. The true density of sunflower seeds was less than the density of water in the moisture content range under study. It showed that the sunflower seed would float when it would be dipped in water. Similar trend of decrease in bulk density of sunflower seeds has been reported by Figueiredo *et al*. (2011) and Gupta and Das (2000). The true density of sunflower (Pioneer) obtained in this study was comparable to those reported in literature. Variation of true density with moisture content can be expressed as.

$\rho_t = 742.98 + 2.22M$ $(R^2 = 0.99)$

Porosity

The variation of porosity of sunflower seeds with moisture content is presented in Fig.-5. The porosity increased linearly from 57.17% to 60.32% with moisture content. Similar trend of decrease in bulk density of sunflower seeds has been reported by Santalla and Mascheroni (2003); Figueiredo *et al.* (2011) and Gupta and Das (2000) for different sunflower varieties. The porosity of sunflower (Pioneer) obtained in this study was comparable to those reported in literature. Variation of porosity with moisture content is expressed as.

$\varepsilon = 55.73 + 0.27M$ $(R^2 = 0.99)$

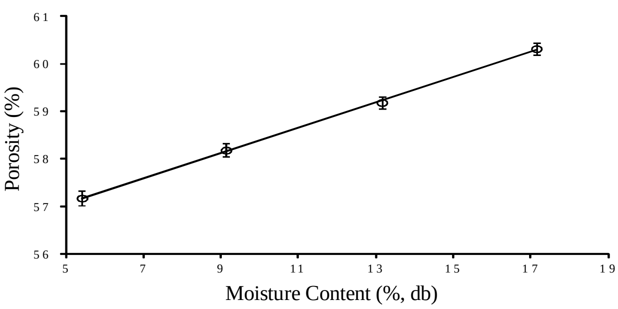

Fig.-5: Effect of moisture content on porosity of sunflower seeds.

Table-4: Test of significance of angle of repose of sunflower seeds.

T-test for Dependent Samples Marked differences are significant at $p<.05000$ for angle of repose of sunflower seeds

	Mean	Std.Dv.	N	Diff.	Std.Dv.	t	df	p
MC	11.20	4.49						
Angle Repose	47.94	2.02	20	-36.73	2.63	-62.30	19	0.00

Angle of Repose

Test of significance of Angle of repose (θ) of sunflower seeds is listed in Table-4. Angle of repose (θ) increased with moisture content of sunflower seed (Fig.-6). The θ increased linearly from 45.1º to 50.3º while moisture content was increased from 5.2 to 25.1% (d.b.) as expressed in equation below

$$\theta = 43.135 + 0.429\,M \qquad (R^2 = 0.98)$$

Gupta and Das (1997) reported increase in θ of sunflower seeds from 33 to 41° with increase in moisture content in the range of 3.6-20.2% (d.b.). Similar behaviour has been reported for squash, sunflower, and pumpkin seeds (Joshi *et al*., 1993; Gupta and Das, 1999; Paksoy and Aydin, 2004). At higher moisture content, seeds tended to stick together, leading to impeded flowability and higher angle of repose. The data would be useful for design of hoppers and storage bins for sunflower seed.

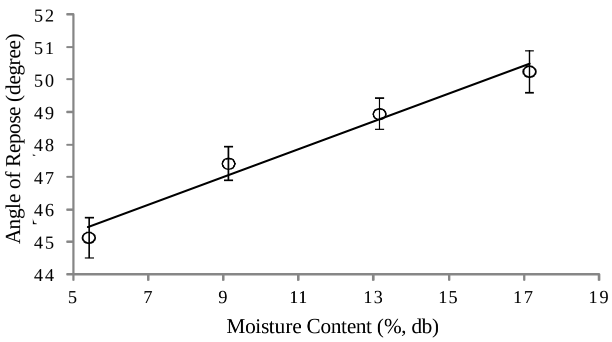

Fig.-6: Effect of moisture content on angle of repose of sunflower seeds.

The seed length width and thickness of sunflower seed (Pioneer variety) increased linearly from 11.45 mm to 12.17 mm, 6.13 mm to 6.64 mm and 4.23 mm to 4.39 mm with increase in moisture content from 5.41% to 17.14% (db) respectively. The bulk density (r_b) decreased linearly from 323.43 kg/m^3 to 310.15 kg/m^3, where as the true density (r_t) increased linearly from 755.17 kg/m^3 to 781.57 kg/m^3 with increase in moisture content. The porosity (e) increased linearly from 57.17% to 60.32% with moisture content. Sphericity of sunflower seeds decreased slightly from 0.59 to 0.58 but, geometric mean diameter of sunflower seeds increased slightly from 6.73 to 7.02 mm with increase in moisture content. The angle of repose (θ) increased linearly from 45.1º to 50.3º while moisture content was increased from 5.41% to 17.14% (d.b.).

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