Effect of Moisture Content on the Physical Properties of Sunflower Seeds (*helianthus annuus l.*) for Development of Power Operated Sunflower Seed Decorticator

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Abstract: *Sunflower (Helianthus annus L.) is one of the principle oil-seed crops and is among the four major oilseed crops in the world. The physical and mechanical properties such as bulk density, true density, angle of internal friction, porosity, static coefficient of friction are necessary for the design of transport, process and storage structures of the sunflower seeds. Hence, a study was conducted to evaluate physical properties of the sunflower seeds under different moisture contents. The physical and mechanical properties were evaluated as a function of moisture content of grain varying from 10% to 14% (w.b).The average length, width, thickness, mass of 100 seeds and angle of repose ranged from 12.54 to 12.91 mm, 5.57 to 5.93 mm, 3.88 to 4.36 mm, 6.08 to 6.36 g and 23.9º to 26.8• as the moisture content increased from 10% to 14 % d.b., respectively. At the above moisture range, as the bulk density decreased linearly from 435 to 432 kg/m³, true density increased linearly from 769.2 to 806.5 kg/m³. The porosity was decreased from 43.5 to 38.7 % and the static coefficient of friction increased from 20 to 22, 18 to 19, 15 to 16 for wood, galvanized steel and glass surfaces, respectively as the moisture content was increased from10-14%.*

Keywords: Sunflower seed, moisture content. angle of repose, true density, porosity, frictional properties

1. Introduction

Sunflower *(Helianthus annuus* L.) is native of Southern USA and Mexico, belonging to Asteraceae family and is among the four major oilseed crops in the world viz., soybean, brassicas, sunflower and groundnut. Sunflower ranks third in the total area planted and fourth in total production. Sunflower seeds are an excellent source of vitamin E. They are also a very good source of vitamin B. In addition, sunflower seeds are a good source of manganese, magnesium, copper, selenium, phosphorous, vitamin B5 and foliate. The annual planting area of sunflower in the world at present is around 23 m.ha with a production of about 33 m.t of seed. The measurement of physical properties of seeds were parameters of great importance for analysis behavior of seeds during handling, drying, processing storage and designing machinery (Kachru, *et al.* 1994). Designing such storage structures and selection of storage equipments without taking these into consideration may yield poor results. Therefore, the determination and consideration of properties such as bulk density, true density, angle of internal friction, static coefficient of friction of grain has an important role (Mohsenin, 1980; Molenda et al., 2002; Kashaninejad et al., 2005). Because the granular products are biological originated, the effect of moisture content of grain is important on physical and mechanical properties of grain (Horabic and Molenda, 1988). The properties of different types of grains and seeds have been determined by other researchers; pigeon pea (Baryeh and Mangope, 2002); caper seeds (Dursun and Dursun, 2005); pistachio nut (Kashaninejad et al. 2005); water melon seeds (Koocheki *et.al* 2007). The moisture content in the sunflower seeds plays a major role in the sowing and storage of the seeds for longer duration. Knowing the moisture dependency is useful for further investigation on drying the seeds. Thus, the objective of this study was to investigate some moisture-dependent physical properties of sunflower seeds, namely, axial dimensions, volume, 100 seed mass, bulk density, true density, porosity, angle of repose, static coefficients of friction on various surfaces as a function of moisture content. These data will determine the behaviour of the sunflower seeds during processing.

2. Material and Methods

The Fully matured good quality sunflower seeds of variety *KBSH-44* were procured from AICRP on sunflower, UAS, GKVK Bangalore for experimental study. Cleaned and well dried raw sunflower seeds were stored in plastic bags to avoid the possible moisture migration into the seed and also to prevent insect attack. Initial moisture contents of the seeds were determined by oven drying at 105 ± 1 ºC for 24 h (Ozarslan, 2002). The initial moisture content of the seeds was 8% d.b. The samples of the desired moisture contents were prepared by adding required the amount of distilled water as calculated from the following relation (Sacilik et al., 2003):

$$\text{Moisture Content, \% (wb)} = \frac{\left(\begin{array}{c}\text{Initial weight}\\\text{of seed /kernel}\end{array}\right) - \left(\begin{array}{c}\text{Final weight}\\\text{of seed/kernel}\end{array}\right)}{\text{Initial weight of seed/kernel}} \times 100$$

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All the physical properties of the seeds were determined at three moisture contents with three replications at each moisture content. The following methods were used to determine some physical properties of Sunflower seeds.

2.1. Size

To determine the average size of the seeds, a sample of 100 seeds was randomly picked and their three major dimensions

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namely, length (*l*), width (*b*) and thickness (*t*) were measured using a digital vernier caliper (Model CD-6BS-Mitutoyo Corporation, Japan) with an accuracy of ±0.01 mm.

2.2. Shape

The shapes of sunflower seeds were determined through visual observations and by comparing with the standard shapes. The procedure for recording the shapes of seeds was given by Kachru (1994).

2.3.100 seeds mass

The mass of 100 seeds was measured using an electronic balance (Model PS200/2000/C/2- RADWAG, Poland) with an accuracy of ± 0.001 g.

2.4. True density

The true density of sunflower seeds was measured using toluene displacement method. 50 ml of toluene was taken in a 100 ml measuring jar and weighed, the sample seeds were poured into the jar. The change in the level of toluene in the jar was recorded. The true densities of the samples were calculated using the formula (Mohsenin, 1970).

$$\text{True density (kg/m}^3) = \frac{\text{Weight of seeds (kg)}}{\text{Volume of seeds (m}^3)}$$

$$\text{Volume of seeds} = \left\{ \begin{array}{c} \text{Final toluene level} \\ \text{in measuring jar} \end{array} \right\} - \left\{ \begin{array}{c} \text{Initial toluene level} \\ \text{in measuring jar} \end{array} \right\}$$

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2.5 Bulk density

The bulk density was determined as per the method described by Mohsenin (1970). The seeds were filled into a container of standard size 10×10×10 cm upto the top level. The excess seeds were removed so that the top surface was perfectly level and even. Then the seeds in the container were weighed by using an electronic balance. The bulk density was calculated using the following formula:

$$\text{Bulk density (kg/m}^3) = \frac{\text{Weight of seeds (kg)}}{\text{Volume of seeds (m}^3)}$$

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2.6. Porosity

The porosity is also known as the packing factor and it was determined from bulk density and true density of grains and expressed by the following expression (Mohsenin, 1970)

$$\text{Porosity (\%)} = \frac{\text{True density - Bulk density}}{\text{True density}} \times 100$$

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2.7. Angle of repose

The angle of repose indicates the cohesion among the individual units of a material. Higher the cohesion, higher is the angle of repose. The dynamic angle of repose of sunflower seeds was measured by the emptying method. For the emptying method, a bottomless cylinder was used. The

cylinder was placed over a plain surface and sunflower seeds were filled in. The cylinder was raised slowly allowing the sample to flow down and form a natural slope. The dynamic angle of repose was calculated from the height and diameter of the pile as:

$$\theta = \tan^{-1} \frac{2h}{D}$$

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Where, θ = Angle of repose (°),
h = Height of the pile (cm) and
D = Diameter of the pile (cm).

2.8. Co-efficient of static friction

The coefficient of static friction (μ_s) was tested on different material surfaces such as plywood, galvanized steel sheet, and glass. The seed was placed on each of the surface and raised gradually by screw until the seed begin to slide. The angle that the inclined surface makes with the horizontal when sliding of the seed begins was measured. The coefficient of static friction was calculated using:

$$\mu_s = \tan\theta$$

………3.6

Where,

μ_s = Co-efficient of static friction
θ = Angle of inclination of material surface.

2.9. Statistical analysis

The results of the machine performance for different treatments of decortication were analyzed using Fisher's Factorial Completely Randomized Design to determine the significant differences among the treatments. Levels of significance was used in F-test at (P=0.05) for the statistical conclusion.

3. Results and Discussion

3.1. Size

The sizes of sunflower seeds at 10 to 12 per cent moisture content (w.b) were lower than the size of seeds at 14 to 16 per cent moisture content (w.b) (Table 1). The average dimensions of seeds at moisture contents between 10 to 16 percent viz., length, width and thickness varied from 12.54 to 13.19, 5.75 to 6.40, 3.88 to 5.91 mm, respectively.

3.2. Shape

By visual observation and standard chart of shapes, the seeds shapes were recorded. The shapes of seeds were identical and were oblong shaped (Mohesion 1970).

3.3. 100 seeds mass

The mass of 100 seeds at different percentages of moisture content are presented in Table 1. The mass of 100 seeds at 10, 12, 14 and 16 percent moisture content were found to be 6.08, 6.28, 6.36, and 6.38 g respectively.

3.4. True density

The true density of seeds at 10 per cent moisture content (769.2 kg/m^3) was found to be lower than the true density of

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seeds at 12 per cent moisture content (772.3 kg/m^3) and the true density at 14 percent moisture content was found to be 806.5 kg/m$^{3.}$ The experimental data was recorded in Table 2.

3.5. Bulk density

The bulk density of seeds significantly varied with moisture content. The bulk density of seeds at 10, 12 and 14 per cent moisture contents were found to be 435 kg/m^3, 434 kg/m^3 and 432 kg/m^3 respectively (Table 2). The bulk density decreased from 435 kg/m^3 to 432 kg/m^3 found to be in agreement with observations of Aydin (2003).

3.6 Porosity

The porosity of seeds at different moisture contents are presented in Table 4.2. The porosity of seeds at 10 per cent moisture content was found to be 43.5 %, whereas porosity values at 12 and 14 per cent moisture content were found to be 41.0 and 38.7 per cent, respectively.

The moisture content had effect on porosity (Fig.3) also. It was high at 10 percent moisture content and low at 14 per cent moisture content. This might be due to the increase in the size of the seeds due to absorption of moisture. This was also observed that the size of the seeds which was higher at 14 percent moisture compared to 10 percent moisture content (Fig.1). Statistically no significant difference was found among in the values of (43.5, 41.0, and 38.7 %) at different moisture contents of the sunflower seeds.

3.7 Frictional properties

3.7.1. Angle of repose
The angle of repose of seeds at 10, 12 and 14 per cent moisture content are presented in Table 3. The angle of repose of seeds at 10 per cent moisture content was found to be 23.9° and the values at 12 and 14 per cent moisture content were found to be 25.50° and 26.80°, respectively.

3.7.2. Co-efficient of static friction
The co-efficient of friction on different surfaces of materials like wood (ply-wood), galvanized iron sheet, and glass were measured using standard techniques and procedures; analyzed statistically and presented in Table 3. The co-efficient of friction for plywood sheet 22, 20 & 22, galvanized iron 19, 19 & 18 and glass 16, 15 & 15 at 10, 12 and 14 percent moisture content, respectively. Similar observations were recorded by Balasubramaniam (2001). The variation in the co-efficient of friction values for different frictional surfaces indicates the behavior of the surface texture of sunflower seeds. Statistically no significant difference was found for the co-efficient of seeds at different among the different moisture contents on different surfaces.

4. Conclusion

The physical properties of sunflower seeds at different moisture contents were studied by using standard procedures. When the recorded data analyzed statistically, it was observed that the physical properties like size, shape, 100 seeds mass ,true density, bulk density, porosity and frictional properties like angle of repose and co-efficient of static friction were determined. Among these, majority of the physical parameters such as size, true density, bulk density and angle of repose has an influence by the change in the moisture content and some significant differences observed between their readings. Sunflower seeds at 16 % moisture content had the highest dimensions in terms of length, width and thickness with values 13.9, 6.40 and 5.19 mm respectively.

5. Future Scope

Some of the *vivo* studies have been done on physical properties of other seeds but not on the sunflower seeds which are used in the development of power operated sunflower seed decorticator. Therefore further research can be done on aero and hydrodynamic properties of sunflower seeds with respect to moisture contents. These properties could help in separation process with blower. These would help in small scale formers for the decortication of sunflower seeds for confectionary purposes.

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Table 1: Physical dimensions of sunflower seeds

Dimension	Moisture content, % (w.b.)				S.Ed. ±	F- test	CD (0.01)
	10	12	14	16			
Length, mm	12.54	12.71	12.91	13.19	0.0365	100.45**	0.1225
Width, mm	05.57	05.75	05.93	06.40	0.0337	228.42**	0.1130
Thickness, mm	03.88	04.02	04.36	05.19	0.0516	257.35**	0.1733
100 seeds mass, g	06.08	06.28	06.36	06.38	0.0564	11.99**	0.1892

NS – Non Significant, ** - Significant at 1 % level

Table 2: Physical properties of sunflower seeds

Trials	Moisture Content (% w.b.)	Volume (ml)	True Density (kg/m³)	Bulk Density (kg/m³)	Porosity (%)
T1	10.0	65	769.2	435	43.5
T2	12.0	68	772.3	434	41.0
T3	14.0	69	806.5	432	38.7
	S.Ed.	3.6124	28.2830	16.6508	1.5773
	CD (0.05)	9.33	6.92	40.74	3.85

Table 3: Frictional properties of sunflower seeds

Trials	Moisture Content, % (w.b.)	Static Coefficient of Friction (degree)			Angle of Repose (degree)
		Plywood	G.I. Sheet	Glass Sheet	Filling
T1	10.0	22	19	16	23.9
T2	12.0	20	19	15	25.5
T3	14.0	22	18	15	26.8
Mean	**13.1**	**21.3**	**18.6**	**15.3**	**25.4**
S.Ed.		**0.80**	**0.75**	**0.57**	**0.98**
CD (0.05)		**1.96**	**1.84**	**1.40**	**2.40**

Figure 2: Influence of moisture content on the mass of sunflower seeds

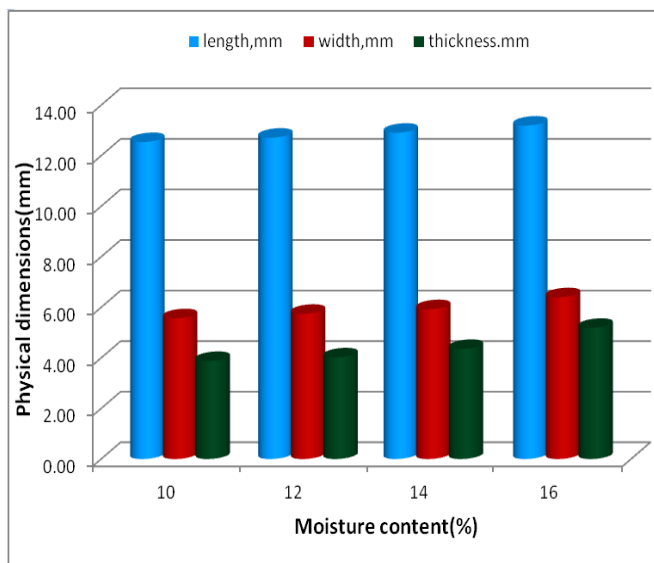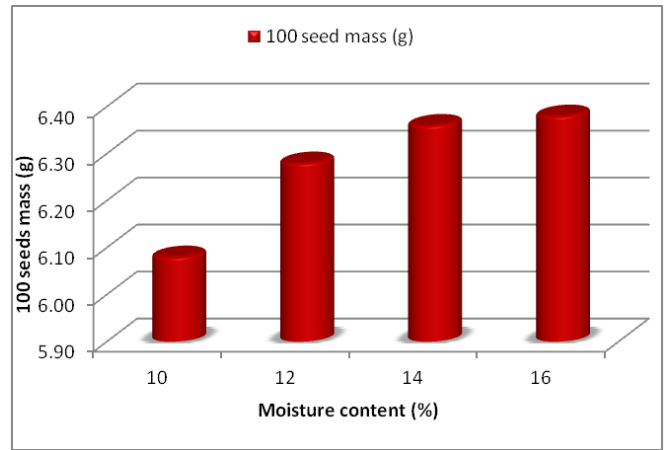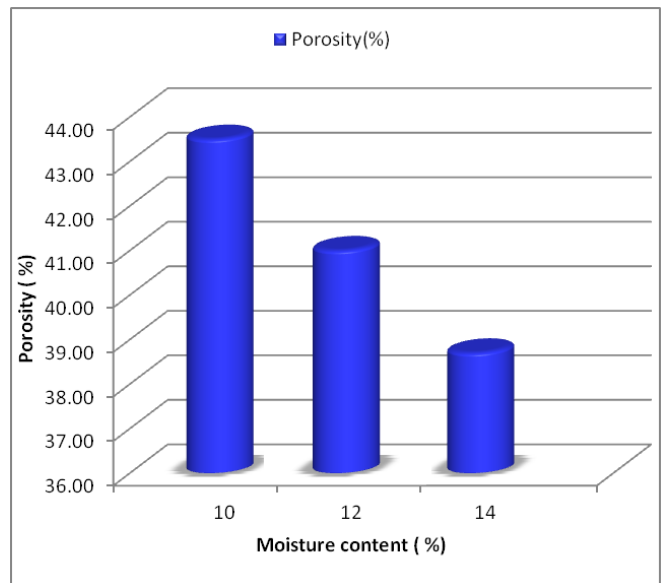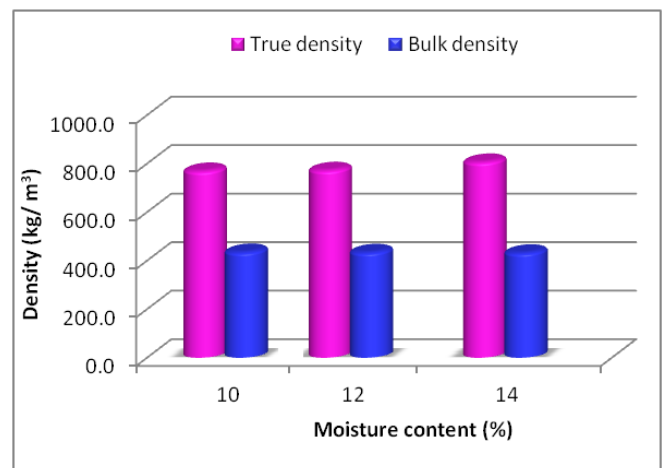**Figure 3:** Influence of moisture content on the porosity of sunflower seeds

Figure 4: Influence of moisture content on the density of sunflower seeds

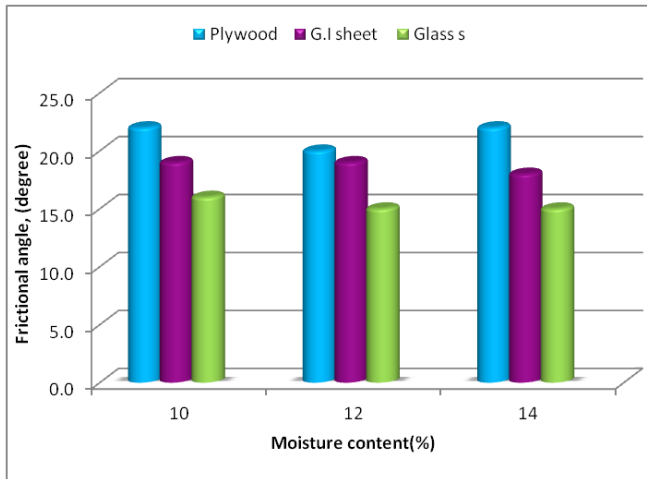**Figure 1:** Influence of moisture content on the size of sunflower seeds

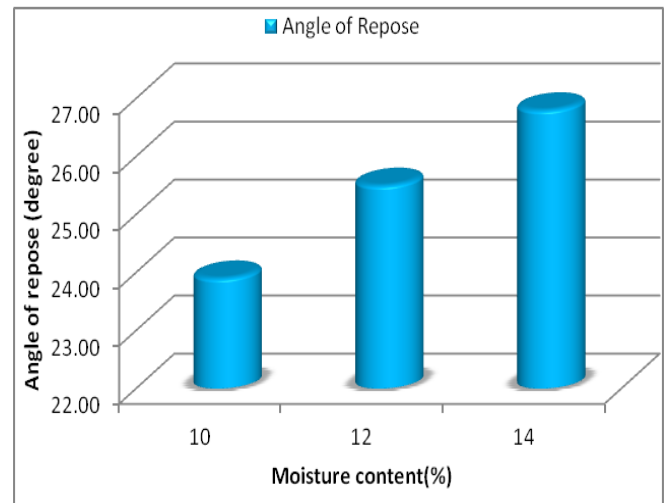**Figure 5:** Influence of moisture content on the angle of friction of sunflower

Figure 6: Influence of moisture content on the angle of repose of sunflower seeds