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# Engineering Properties of Flaxseed (LC 2063) at Different Moisture

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## Abstract

Engineering properties of flaxseeds were evaluated as a function of moisture content. The geometric mean diameter and sphericity of the seed were 3.808 mm and 0.609 respectively. In the moisture range from 10-18% d.b., the length of the rewetted seed ranged from 4.698 to 4.758 mm, width from 2.400 to 2.360 mm, thickness from 0.999 to 2.157 mm, geometric mean diameter (GMD) from 2.240 to 2.893 mm, sphericity from 0.477 to 0.478. The thousand kernel weight (TKW) increased from 7.195 to 7.403 g, bulk density decreased from 613.818 to 547.174 kg/m3, true density increased from 1105.326 to 1183.200 kg/m3, porosity increased from 44.467 to 49.954 %, hardness decreased from 74.411 to 40.828 N, initial cracking force decreased from 52.470 to 34.019 N and area ranged from 6.140 to 6.406 Nmm. In the same moisture range, the static coefficient of friction varied from 0.320 to 0.420 for different surfaces, while the angle of repose varied from 16.969 to 24.699 for seed. Lightness (L), a value (red-green axis) and b value (yellow-blue axis) of seed decreased from 42.94 to 40.360, 7.22 to 4.96, and 10.70 to 8.30, respectively, with increase in moisture content of seed from 10 to 18 %, d.b.

## INTRODUCTION

Flax is an important ingredient that has tremendous nutritional potential for cereal products. Flax commonly known as linseed (*Linum usitatissium*) is a native to region extending from the eastern Mediterranean to India. The fruit is a round, dry capsule, 5-9 mm diameter containing several glossy brown seeds shaped like an apple pip, 4-7 mm long. Commercially, flax is grown for both for its seed and for its fiber. Flax seeds come in two varieties (i) brown (ii) yellow or golden. Some physical properties of this seed and comparison with other seeds are considered to be necessary for the proper design of equipment for handling, conveying, separation, dehulling, drying, mechanical expression of oil, storage and other processes (Kachru et al., 1993). Despite an extensive research, no published literature was found on the detailed physical properties of flaxseed and their dependency on operational parameters, which would be useful for the design of dehulling and storage systems. The properties of different types of grains and seeds have been determined by other researchers such as Ougt (1998) for white Lupin; Baryeh (2002) for millet; Cetin (2007) for barbunia bean; Ogunjimi et al. (2002) for locust bean seed and Coskun et al. (2006) for sweet corn seed. Bulk density, true density, and porosity can be useful in sizing grain hoppers and storage facilities. They can affect the rate of heat and mass transfer of moisture during aeration and drying processes. Grain bed with low porosity will have greater resistance to water vapor escape during the drying process, which may lead to higher power to drive the aeration fans. The static coefficient of friction is used to determine the angle at which chutes must be positioned in order to achieve consistent flow of materials through the chute. Such information is useful in sizing motor requirements for grain transportation and handling (Ghasemi Varnamkhasti et al., 2007).

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In this study, some physical properties of flaxseed were determined, namely, size and shape, GMD, sphericity, TKW, bulk and true densities, porosity, static coefficient of friction against the different material surfaces and angle of repose, hardness, initial cracking force and color measurement by colorimeter at various moisture contents in the range of 10-18% d.b. Although moisture content has been reported to influence several physical properties, Gupta and Prakash (1992) reported non-significant variations of sphericity for a wide range of moisture contents in safflower seed. An increase in seed moisture content was found to increase the angle of repose in fababean (Fraser et al., 1978) as well as the coefficient of static friction in safflower seeds (Gupta and Prakash, 1992). Thus, various physical properties of seeds and their fractions are dependent on moisture content and appear to be important in the design of handling and processing equipment.

## MATERIALS AND METHODS

For this study, the short duration variety of flaxseed (Var. LC 2063) maturing within 155-160 d and widely grown in Punjab, India was selected. Bulk sample consisting of 16 kg of seeds was procured from the Punjab Agricultural University, Ludhiana during July 2012. Seeds were packed in double layered low density polyethylene bags and stored at low temperature (4±1$^{o}$C). The method of random sampling was used for sample preparation (Dutta et al., 1988). For each individual seed three principal dimensions namely length, width and thickness were measured using a digital vernier caliper (accuracy 0.1 mm). Because of the irregular shape of the flaxseed, only the greatest values of both width and thickness have been taken. To obtain the mass, each seeds were weighed on a precision electronic balance reading to 0.0001 g.

### Moisture content

The moisture content of seed was determined by an oven drying method (ISI, 1966). To study the effect of moisture content of the sample on some of its physical properties, samples of seed at desired moisture levels were prepared by adding calculated amounts of distilled water according to relation (Eq. 1) given by Sacilik et al. (2003) and sealed in separate polyethylene bags. The samples were kept at low temperature (4±1$^{o}$C) in a refrigerator to avoid the growth of microorganisms. Before starting a test, the required quantity of the sample was taken out of the refrigerator and was allowed to warm up to room temperature. The initial moisture content of the seeds was 5.7 % d.b

$$Q = \frac{W_i (M_f - M_i)}{100 - M_i} \quad \ldots\ldots \quad (1)$$

Where $W_i$, is the initial mass of the sample in kg; $M_i$, is the initial moisture content of the sample in % d.b.; and $M_f$, is the final moisture content of sample in % d.b. The samples were then poured into separate polyethylene bags and the bags sealed tightly. The samples were kept at (4±1)°C in a refrigerator for a week to enable the moisture to be distributed uniformly throughout the samples. Before starting a test, the required quantity of the seeds were taken out of the refrigerator and allowed to equilibrate to the room temperature for about 2 h (Singh and Goswami, 1996). All the physical properties of the seeds were determined at five moisture contents in the range of 10 to 18% d.b. with 15 replications at each moisture contents.

### Geometric mean diameter and sphericity

The geometric mean diameter (GMD) and sphericity (Ø) of seeds were determined using the following expressions.

$$GMD = (LWT)^{1/3} \quad (2)$$

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

Where L, W and T are length, width and thickness respectively.

**Bulk density and true density**

The bulk and true density for both seed at different moisture levels were determined. The bulk density ($\rho_b$) is the ratio of the mass sample of the grain to its total volume. It was determined by filling a 1000 ml container with grain from a height of 15 cm, striking the top level and then weighing the contents (Mohsenin, 1970). Bulk density for each replication was calculated from the following relation:

$$\rho_b = \frac{W_s}{V_s} \qquad (4)$$

Where: the $\rho_b$ is the bulk density in kg/m$^3$; Ws is the weight of the sample in kg; and $V_s$ is the volume occupied by the sample in m$^3$.

The true density (($\rho_t$) was defined as the ratio between the mass of flaxseeds and the true volume of the seeds, and was determined using the toluene ($C_7H_8$) displacement method. Toluene was used instead of water because it is absorbed by seeds to a lesser extent. The volume of toluene displaced was found by immersing a weighted quantity of fennel seeds in the measured toluene (Tavakkoli et al., 2009).

**Porosity**

The porosity was calculated from the values of bulk and true densities using the following relationship (Mohsenin, 1970)

$$\text{Porosity} = \frac{(\text{True density} - \text{Bulk density}) \times 100}{\text{True density}} \qquad (5)$$

**Angle of repose**

The emptying or dynamic angle of repose was measured for five moisture contents. For such measurement, a plywood box with a removable front panel was filled with grains. The front panel was quickly removed, allowing the seeds to flow and assume a natural slope (Dutta et al. 1988). The angle of repose was calculated from the measurements of the vertical depth and radius of spread of the sample.

**Static coefficient of friction**

The static coefficient of friction for seed was measured against two structural materials, namely mild steel and galvanized iron. A galvanized iron cylinder of 100 mm diameter and 50 mm height was placed on an adjustable tilting plate, faced with the test surface, and filled with the sample. The cylinder 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 the box just started to slide down and the angle of tilt was read from a graduated scale (Joshi et al., 1993). All the experiments were carried out three times, unless stated otherwise, and the average values reported.

**Texture analysis**

Texture of the flaxseeds was evaluated on texture analyzer (TA-XT2i) (Bourne 1982). Flaxseed subjected to compression test to measure hardness (N), initial cracking force (N) and area (Nmm) at different moisture content.

**Color analysis**

Colour of flaxseed measured using Hunter Lab Colorimeter (Kimura et al., 1993). L, a, b values and hue angle of flaxseed determined.

## RESULTS AND DISCUSSION

**Seed dimensions**

In the moisture range from 10-18% d.b., the length of the rewetted seed increased from 4.698 to 4.758 mm, width ranges from 2.40 to 2.36 mm and thickness ranges from 0.999 to 2.157 mm as shown in Fig. 1.

**Geometric mean diameter and sphericity**

The geometric mean diameter of flaxseed was higher than those reported for pigeonpea, muskmelon and longmelon seed (Ramakrishana, 1986) and was found close to safflower. Sphericity of sunflower seed was much lower than those reported for pigeonpea (Shepherd and Bhardwaj, 1986). GMD of flaxseed ranges from 2.240 to 2.893 mm (Fig. 2) and sphericity ranges from 0.477 to 0.478 (Fig. 3) as the moisture content increased from 10 to 18% d.b.

### Thousand kernel weight

The thousand kernel weight of seeds was measured in the moisture range between 10 and 18% d.b. (Fig. 4). The thousand kernel weight increased with the increase in moisture content for seed. It increases from 7.195 g to 7.403 g. The results showed that the mass of 1000 seeds was lower than lentils (Makanjuola, 1972), millet (Baryeh, 2002) and karingda seeds (Suthar and Das, 1996).

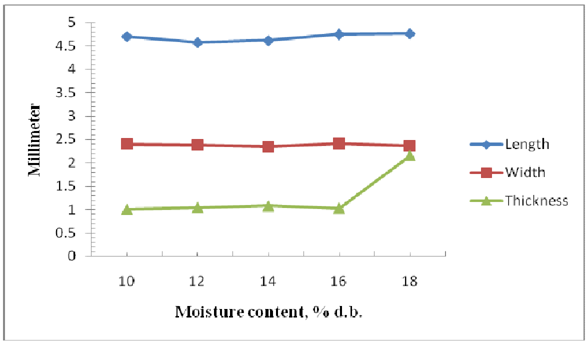


**Fig.1.** Variation of grain dimensions of flaxseed at different moisture content

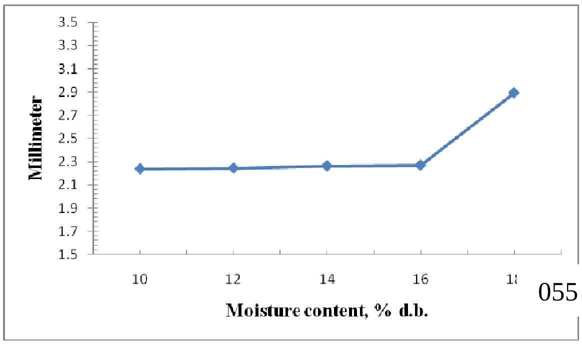


**Fig.2.** Variation of geometric mean diameter of flaxseed at different moisture content

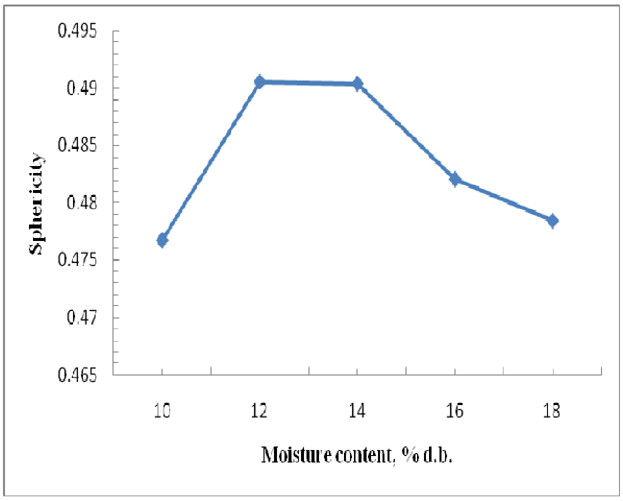


**Fig.3.** Variation of sphericity of flaxseed at different moisture content

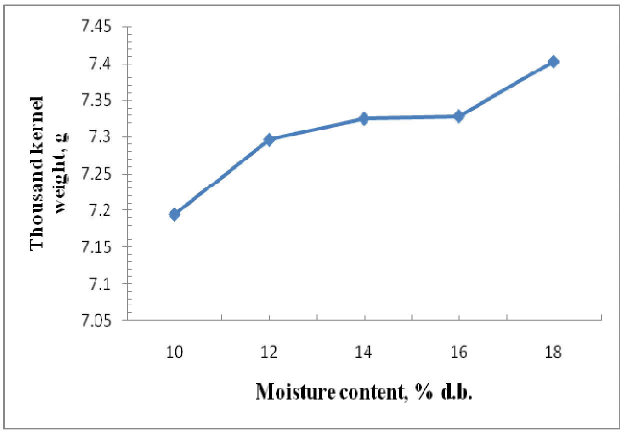


**Fig.4.** Variation of thousand Kernel weight of flaxseed at different moisture content

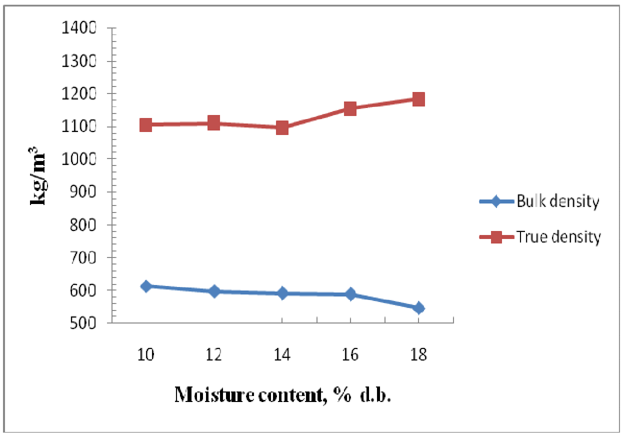


**Fig.5.** Variation of bulk density and true density of flaxseed at different moisture content

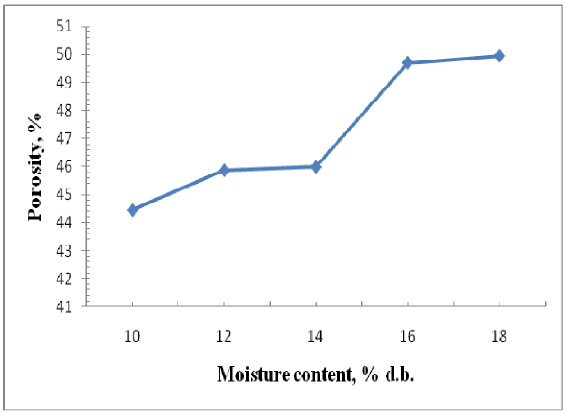


**Fig.6.** Variation of porosity of flaxseed at different moisture content

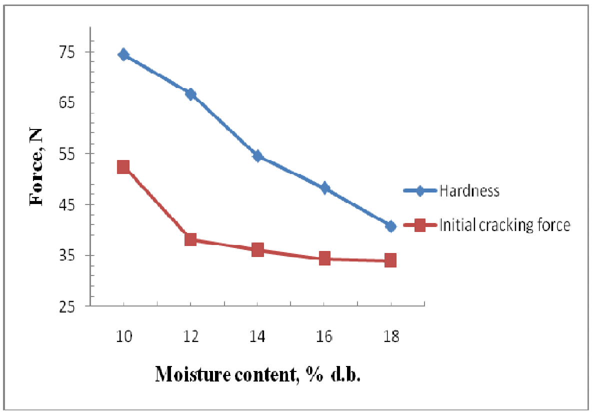


**Fig.9**. Variation of hardness and of initial cracking force of flaxseed at different moisture content

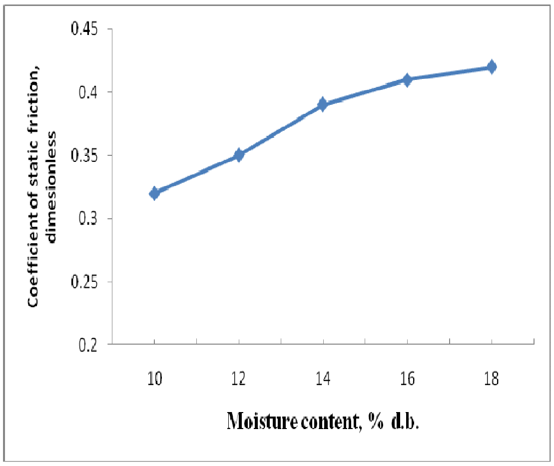


**Fig.7.** Variation of coefficient of static friction of flaxseed at different moisture content

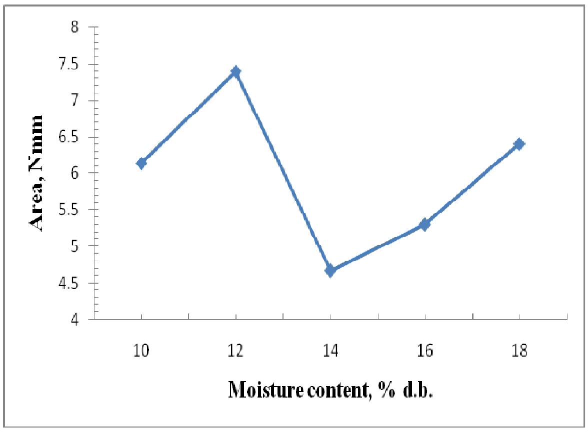


**Fig.10.** Variation of area of flaxseed at different moisture content

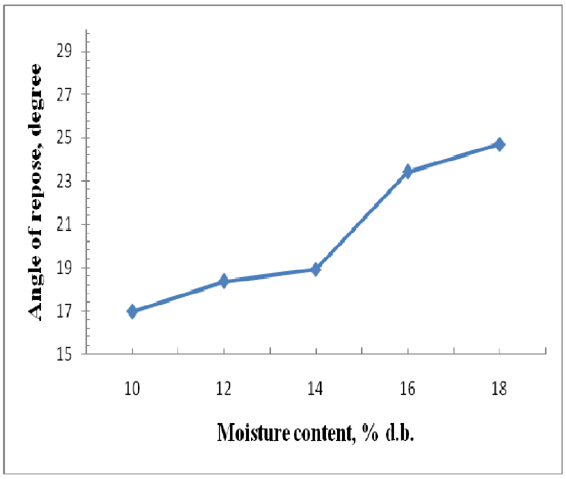


**Fig.8.** Variation of angle of repose of flaxseed at different moisture content

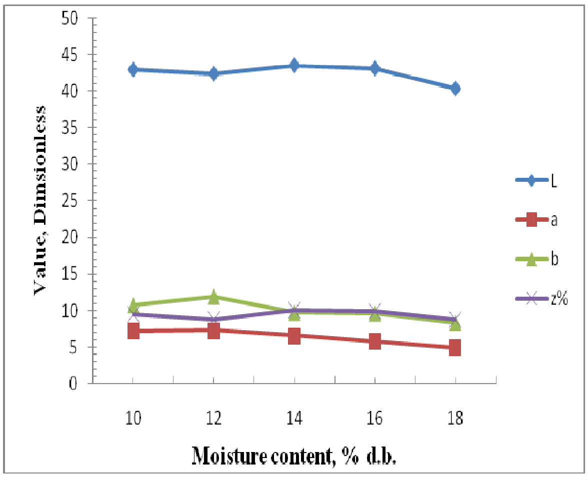


**Fig.11.** Variation of color value of flaxseed at different moisture content

## Bulk density

The bulk density of seeds was measured in the moisture range between 10 and 18% d.b. The bulk density decreased with the increase in moisture content for seed (Fig. 5). Thus, it appears that the increase in volume was more than proportional to the increase in mass of the bulk seed. The bulk density of flaxseed was compared with those of other grains and it was observed that the bulk density of seed at a given moisture level was lower than those of safflower (Gupta and Prakash, 1992).

## True density

The true density of seed was found to vary from 1105.326-1183.20 kg/m$^3$, when the moisture level increases from about 10 to 18% d.b. (Fig. 5). Graph show that the true density of seeds varies linearly with moisture content similar to other grains such as corn and hard red winter wheat. The true density of flaxseed was found to be less than that of safflower (Gupta and Prakash, 1992) and pumpkin seeds (Joshi et al., 1993).

## Porosity

The porosity was evaluated for flaxseed using Eqn 5. It increased from 44.467 to 49.954 % for seeds when the moisture content changed from 10 to 18% d.b. (, Fig. 6). Higher porosity provides better aeration and water vapor diffusion during deep bed drying. Similar trend was reported for hazel nuts (Aydin, 2002) gram (Dutta et al., 1988), sunflower (Gupta and Das, 1997).

## Static coefficient of friction

The experimental results showing the effect of moisture content and structural surfaces on the static coefficient of friction are given in Fig. 7 for seed, friction increased with moisture content against both mild steel and galvanized iron. Further, these values were slightly higher for mild steel than for galvanized iron. This may be due to the smoother surface of galvanized iron compared with mild steel. The difference in coefficients for seed on both the surfaces was found to be significant at the 1% level at moisture contents between 10 and 18% d.b. Similar findings were reported for millet (Baryeh, 2002), pumpkin seeds (Joshi et al., 1993), and karingda seeds (Suthar and Das, 1996), corn seed (Seifi and Alimardani, 2010)

## Angle of repose

The angle of repose of flaxseed at different moisture contents are shown in Fig. 8. It increased from 16.969 to 24.699 for seed in the moisture range of 10 to 18% d.b.. Pigeonpea, fababean, safflower and oilbean seed may be comparatively smoother or have a greater sphericity thus enabling them to slide more easily on one another, resulting in a lower value of angle of repose. A linear increasing angle of repose as the seed moisture content increases has also been noted by Chandrasekar and Viswanathan (1999) for coffee, Oje and Ugbor (1991) for oilbean seeds, Joshi et al. (1993) for pumpkin seeds.

## Hardness and initial cracking force

The hardness and initial cracking force of flaxseed at different moisture contents are shown in Fig. 9. Both hardness and initial cracking force decreased from 74.411 to 40.828 N and 52.470 to 34.019 respectively, for seed in the moisture range of 10 to 18% d.b. With increase in moisture content both hardness and initial cracking force decreased. A linear decreasing in hardness and initial cracking force, as the flaxseed moisture content increases has not been reported any literature. Area for flaxseed ranges from 6.14 to 6.406 Nmm (Fig.10).

## Color

The color of flaxseed at different moisture contents are measured in terms of L, a, b and z% value (Fig. 12). Lightness (L) of seed decreased from 42.940 to 40.360, a value (red-green axis) decreased from 7.22 to 4.96, b value (yellow-blue axis) decreased from 10.70 to 8.30 with increase in moisture content of seed from 10 to 18 %, d.b. A linear decreasing in L, a and b value as the flaxseed moisture content increases has been observed.

## CONCLUSIONS

The mean geometric mean diameter and sphericity of seed were 3.808 mm and 0.609 respectively. In the moisture range from 10-18% d.b., the length of the rewetted seed increased from 4.698 to 4.758 mm, width ranges from 2.4 to 2.36 mm, thickness ranges from 0.999 to 2.157 mm, geometric mean diameter (GMD) ranges from 2.240 to 2.893 mm, sphericity ranges from 0.477 to 0.478, thousand kernel weight (TKW) increased from 7.195 to 7.403 g, bulk density decreased from 613.818 to 547.174 kg/m$^3$, true density increased from 1105.326 to 1183.20 kg/m$^3$, porosity increased from 44.467 to 49.954 %, hardness decreased from 74.411 to 40.828 N, initial cracking force decreased from 52.470 to 34.019 N and area ranges from 6.14 to 6.406 Nmm. The static coefficient of friction of seed was lower and varied from 0.320 to 0.420 for seed with increase in moisture content from 10- 18% d.b. The angle of repose increased from 16.969 to 24.699 for seed in the moisture range of 10-18% d.b. A linear decrease in L, a and b value as the flaxseed moisture content increased has been reported.

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