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Effect of Moisture Content on the Physical Properties of Fibered Flaxseed

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Effect of Moisture Content on the Physical Properties of Fibered Flaxseed*

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Abstract

The physical properties of fibered flaxseed were investigated within moisture content varying from 6.21 to 16.29%. The length, width, thickness and geometric mean diameter increased from 4.20 to 4.44mm, 1.99 to 2.13mm, 0.91 to 0.95mm, and 1.95 to 2.06mm, respectively in the moisture content range. One thousand seed weight increased linearly from 4.22 to 4.62g. The bulk density decreased from 726.783 to 611.872kg/m^3, while the true density increased from 1165.265 to 1289.341kg/m^3 in the moisture content range. The porosity values of flaxseed increased linearly from 37.67 to 52.54%. The highest static coefficient of friction was found on the plywood surface, while the lowest on the stainless steel surface. The static coefficient of friction increased from 0.467 to 0.972, 0.442 to 0.864, 0.492 to 0.927, and 0.490 to 0.845 for plywood, stainless steel, aluminum sheet and galvanized iron, respectively. The angle of repose increased linearly from 25.7° to 33.8° in the moisture content range. The results are necessary for design of equipment to handling, transportation, processing, and the storage of flaxseed.

KEYWORDS: Flaxseed, physical properties, moisture content, density, coefficient of friction, angle of repose

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1. INTRODUCTION

Flaxseed, which is also called linseed, is the seed from the flax plant (***Fig. 1***). The plant is native to West Asia and the Mediterranean. The plant can be classified into oily flaxseeds and fibered flaxseeds. Today flaxseed is mainly grown in Canada, Argentina, America, China and India (Shi, 1996).

Flaxseed has been cultivated since at least 5000 BC, and it was used by the Egyptians to make cloth to wrap their mummies, and many ancient books of Europe and Asia contain lots of references to the plant indicating that flax spinning and weaving were household industries in antiquity. Flaxseed is abundant in many nutrients, such as polyunsaturated fatty acid, protein, and lignans. Many researchers have investigated the nutritional elements of the plant (Zhang et al., 2007, Wang et al., 2007). The cloth which was made by flaxseed has some excellent properties, such as static-free, aerated, dustless, comfortable, and cleaned easily. Today flaxseed is popular to the consumers as a "natural commodity".

The dimensions of global fruit capsules vary 6~8mm in length, 6~7mm in diameter and contain 10 seeds approximately. The seed is flat and oval with a pointed tip. It has a smooth surface and range in color from medium, reddish-brown to a light yellow. The dimensions of flaxseed vary approximately 3.0~6.4mm in length, 1.8~3.4mm in width and 0.5~1.6mm in thickness (Freeman, 1995).

Fig 1. Flaxseed

Information regarding to the physical properties of flaxseed is very important in the design for harvesting, transporting, cleaning, separating, packing, storing and processing it into different foods. Since some currently used systems have been designed without taking these criteria into consideration, the resulting designs lead to inadequate applications. These cases result in a reduction in work efficiency and increase in product losses. Therefore, determination and consideration of these properties play an important role in designing these equipments.

The knowledge of flaxseed such as dimensions of the seed, porosity, density, coefficient of static friction, angle of repose, etc. is necessary to design of flaxseed processing equipment. For instance, dimensions and porosity of the seed are the most important for packing. The density of the seed is significant in numerous technological processes and in the evaluation of product quality. The coefficient of static friction and angle of repose play important role in transports of goods and storages facilities.

Moisture content affects physicals properties significantly, and many studies have been reported for fruits, grains and seeds, such as hemp seed (Sacilik, Öztǖrk and Keskin, 2003), green gram (Nimkar and Chattopadhyay, 2001), sugarbeet seed (Dursun, Tuĝrul and Dursun, 2007), dried pomegranate seed (Kingly et al., 2006), caper seed (Dursun and Dursun, 2005), quinoa seed (Vilche, Gely and Santalla, 2003) and Locust bean seed (Olajide and Ade-Omowaye, 1999), but to our best knowledge, there are no studies on the effect of moisture content on the physical properties of fibered flaxseed.

The objective of the study was to investigate the effect of moisture content on physical properties of flaxseed namely, dimensions, geometric mean diameter, one thousand seed weight, bulk density, true density, porosity, static coefficient of friction against four surfaces, and angle of repose at different levels of moisture content.

2. MATERIALS AND METHODS

2.1 Materials

The dry flaxseeds were obtained from Heilongjiang Province of China, and were used for all the experiments in this study. Flaxseeds were kept in cooling bags for transporting to the laboratory. The seeds were cleaned manually to remove all foreign matter such as dust, dirt, stones and chaff as well as immature, broken seeds. The initial moisture content of the seeds was determined by oven drying at 105±1°C for 24 h. The initial moisture content of the seeds was 6.65% dry basis (d. b.).

2.2 Preparation of samples

The samples of the desired moisture contents were prepared by adding the amount of distilled water as calculated from the following equation:

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

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Where: Q is the amount of distilled water, W_i is the weight of seed at initial moisture content, M_f is desired moisture content of seed, M_i is initial moisture content of seed.

The samples were then poured into separate polyethylene bags and the bags were sealed tightly. The samples were kept at 5°C in a refrigerator for 7 days to enable the moisture to distribute uniformly. All the physical properties were determined at the moisture contents of 6.21, 8.62, 11.43, 13.37, and 16.29%. Moisture content of the samples was determined by oven drying at 105±1°C for 24h. The seed moisture content range investigated 6.21~16.29% (d. b.) since transportation, storage and handling operations of the seeds are performed in this moisture range. Before starting a test, the required quantity of the seeds was taken out of the refrigerator and allowed to equilibrate to the room temperature for about 2h.

All the physical properties of the seeds were assessed at different moisture content with five replications.

2.3 Methods

2.3.1 Seed dimensions

One hundred seeds were randomly selected from the sample. The three linear dimensions, namely, length, width and thickness of each of the 100 seeds were measured with a digital caliper compass reading to 0.01mm.

The geometric mean diameter (D_g) of the seed was calculated by using the following equation:

$$D_g = (LWT)^{1/3}$$

Where: L is the length, W is the width and T is the thickness.

2.3.2 One thousand seed weight

The mass of seeds was determined on 100 randomly selected seeds and converted to a 1000-seed-basis.

2.3.3 Bulk density and true density

The bulk density is the ratio of the mass sample of the seeds to its total volume. It was determined by filling a 1000ml container with seeds from a height of about 15cm, striking the top level and weighing the contents (Akaaimo and Raji, 2006; Mwithiga and Sifuna, 2006).

The true density defined as the ratio of mass of the sample to its true volume, was determined using the toluene displacement method in order to avoid absorption of water during experiment. Fifty milliliter of toluene was placed in a 100ml graduated measuring cylinder and 5g seeds were immersed in the toluene (Mwithiga and Sifuna, 2006; Ovelade et al., 2005). The amount of displaced toluene was recorded from the graduated scale of the cylinder. The ratio of weight of seeds to the volume of displaced toluene gave the true density.

2.3.4 Porosity

The porosity is the fraction of the space in the bulk grain which is not occupied by the grain. The porosity of the bulk seed was calculated from the values of true density and bulk density using the equation:

$$\varepsilon = \frac{\rho_t - \rho_b}{\rho_t} \times 100$$

Where: ε is porosity, ρ_t is the true density and ρ_b is the bulk density.

2.3.5 Coefficient of static friction

The coefficient of static friction was determined with respect to four surfaces: plywood, stainless steel, aluminum sheet, and galvanized iron. These are common materials used for transportation, storage and handling of grains, pulses and seeds construction of storage and drying bins. To determine the coefficient of static friction, a hollow metals cylinder 50mm diameter and 50mm high and open at both ends was used. The cylinder was filled by the seeds and placed on an adjustable tilting table. The surface was raised up gradually by a screw device until the cylinder just starts to slide down. The angle of the surface was read from a scale and the static coefficient of the friction was read as the tangent of this angle (Özarslan, 2002; Yalçin, Özarslan and Akbaş, 2007).

2.3.6 Angle of repose

To determine angle of repose, a box measuring 300mm×300mm×300mm, having a removable front panel was used. The box is filled with the seeds, and the front panel was quickly removed, allowing the seeds to flow to their natural slope. The angle of repose was calculated from measurements of seed free surface depths at the end of the box and midway along the sloped surface and horizontal distance from the end of the box to this midpoint (Mwithiga and Sifuna, 2006; Dursun, Tuĝrul and Dursun, 2007; Sacilik, Öztűrk and Keskin, 2003).

2.3.7 Statistical analysis

The analysis of variance (ANOVA) was carried out based on the experimental data by using the SAS statistical package, and p values were used to determine the extent of effect of moisture content on the properties.

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3. RESULTS AND DISCUSSION

3.1 Effect of moisture content on the seed dimensions

The length, width and geometric mean diameter of seed increased from 4.20 to 4.44mm, 1.99 to 2.13mm, 1.95 to 2.06mm, respectively, with increase in moisture content from 6.21 to 16.29%. The relationship between length, width and geometric mean diameter and moisture content was found to be linear:

$$L = 0.0245M_c + 4.0245$$

$$W = 0.0128M_c + 1.9186$$

$$D_g = 0.0088M_c + 1.9213$$

Where: M_c is moisture content in %, with values for the coefficient of determination, R^2 of 0.9595, 0.9974, and 0.9714, respectively.

The thickness increased from 0.91 to 0.95mm with increase in the moisture content from 6.21% to 11.43% and decreased to 0.92mm with further increase in moisture content to 16.29%. The relationship between thickness and moisture content is presented as:

$$T = -0.0012{M_c}^2 + 0.0286M_c + 0.7783$$

with a value for R^2 of 0.9569.

The result indicates that the seeds expanded in length, width, thickness and geometric mean diameter within the moisture range 6.21~16.29%. The total average expansion was largest along the flaxseed length and least along its thickness. Some other grains were found to have the same properties, such as amaranth seeds (Abalone et al., 2004), green gram (Nimkar and Chattopadhyay, 2001), and moth gram (Nimakar, Mandwe and Dudhe, 2005). This could be due to the different expansion along the length and the thickness with the water absorption. The geometric mean diameter of flaxseed is lower than coriander seeds (Coşkuner and Karababa, 2007), hemp seed (Sacilik, Öztȕrk and Keskin, 2003). sugarbeet seed (Dursun, Tuĝrul and Dursun, 2007), dried pomegranate seed (Kingly et al., 2006), and higher than quinoa seed (Vilche, Gely and Santalla, 2003), tef seed (Zewdu and Solomon, 2007).

3.2 Effect of moisture content on one thousand seed weight

One thousand seed weight increased linearly from 4.22 to 4.62g when the moisture content was increased form 6.21 to 16.29%. The relationship between one thousand seed weight (W_{1000}) and moisture content (M_c) can be described as follows:

$$W_{1000} = 0.0398M_c + 3.9637$$

with a value for R^2 of 0.997. The one thousand seed weight of flaxseed at different moisture content is lower than caper seed (Dursun and Dursun, 2005), similar to cumin seed (Singh and Goswami, 1996).

3.3 Effect of moisture content on bulk density

The bulk density of the seeds at different moisture content decreased linearly from 726.783 to 611.872kg/m^3 within the moisture content range of 6.21~16.29% (d. b.). The relationship between bulk density (ρ_b) and moisture content (M_c) can be expressed as:

$$\rho_b = -11.107M_c + 791.46$$

with a value for R^2 of 0.99. The bulk density of flaxseed at different moisture content is higher than sunflower seed (Gupta, Das, 1997), hemp seed (Sacilik, Öztūrk and Keskin, 2003). At the lowest moisture content (6.21%) and the highest moisture content (16.29%), the bulk density of flaxseed is similar to pea seed (Yalçin,. Özarslan and Akbaş, 2007) and cotton seed (Özarslan, 2002). The decrease in bulk density of flaxseed with increase in moisture content indicates the increase in volumetric expansion in the seed is greater than weight. Some other grains have the same trend, such as fenugreek seed (Altuntaş, Özgöz and Taşer, 2006), vetch seed (Yalçin and Özarslan, 2004), cowpea seed (Yalçin, 2007).

3.4 Effect of moisture content on true density

The true density of seeds increases from 1165.265 to 1289.341kg/m^3 within the seed moisture content range of 6.21~16.29%. The relationship of true density (ρ_t) and moisture content (M_c) can be expressed as:

$$\rho_t = 12.075M_c + 1090.4$$

with a value for R^2 of 0.99. The true density of flaxseed at different moisture content is higher than sweet corn seed (Coşkun, Yalçin and Özarslan, 2006), dried pomegranate seed (Kingly et al., 2006). At the lowest moisture content (6.21%) and the highest moisture content (16.29%), the true density of flaxseed is similar to cotton seed (Özarslan, 2002) and moth gram (Nimakar, Mandwe and Dudhe, 2005).

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3.5 Effect of moisture content on porosity

The porosity of seeds was found to increase from 37.668% to 52.544% within moisture content range of 6.21~16.89%. The linear relationship between the porosity (ε) and moisture content (M_c) can be expressed as:

$$\varepsilon = 1.4442\, M_c + 29.222$$

with a value for R^2 of 0.99. The similar trend was found in other grains, for example, barbunia bean (Cetin, 2007), lentil seed (Amin, Hossain and Roy, 2004), and hemp seed (Sacilik, Öztǖrk and Keskin, 2003).

3.6 Effect of moisture content on static coefficient of friction

The result of static coefficient of friction of seeds obtained experimentally on four surfaces within moisture content range of 6.21~16.29% (d. b.) were shown in ***Fig.2***. It indicted that the aluminum sheet had the highest static coefficient of friction (0.492) at the lowest moisture content (6.21%) followed galvanized iron (0.49), plywood (0.47), and stainless steel (0.44). At the highest moisture content (16.29%), plywood (0.97) had the highest coefficient of friction followed by aluminum sheet (0.93), stainless steel (0.86), and galvanized iron (0.85), respectively. The static coefficient of friction of flaxseed increased linearly with the moisture content range and varied according to the surface. The sliding characteristics are diminished with increasing moisture content depends on their mucilage contents. The relationships between static coefficient of friction (μ) and moisture content (M_c) were expressed as follows:

$$\mu_p = 0.0496 M_c + 0.1613$$

$$\mu_s = 0.0415 M_c + 0.1952$$

$$\mu_a = 0.0434 M_c + 0.2183$$

$$\mu_g = 0.0354 M_c + 0.2656$$

Where: μ_p, μ_s, μ_a, and μ_g is static coefficient of friction against plywood, stainless steel, aluminum sheet, and galvanized iron, with all values for R^2 of 0.99.

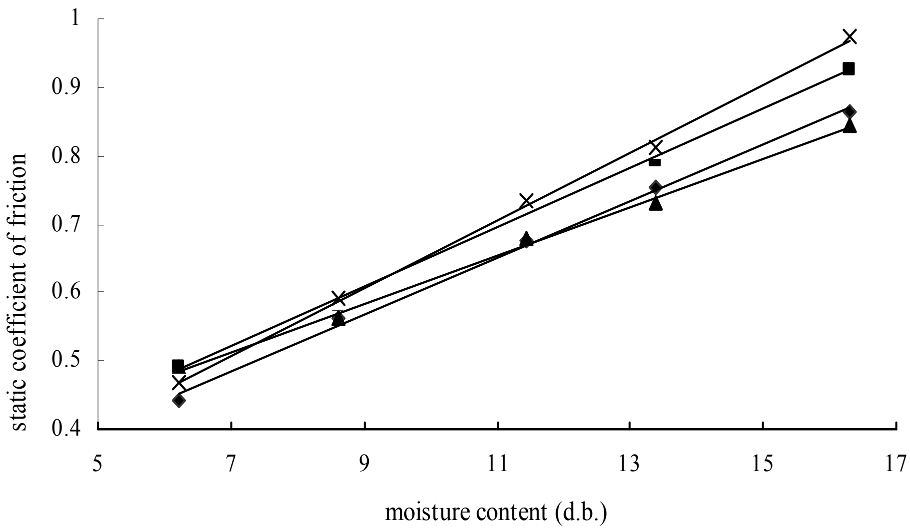

Fig 2. Effect of moisture content on static coefficient of friction against four surfaces.

□, *stainless steel;* ▲, *galvanized iron;* ■, *aluminum sheet;* ×, *plywood*

The similar results for plywood, galvanized iron, stainless steel and aluminum sheet were reported for chick pea seed (Konak, Çarman and Aydin, 2002), caper seed (Dursun and Dursun, 2005), green gram (Nimkar and Chattopadhyay, 2001) and sugarbeet seed (Dursun, Tuĝrul and Dursun, 2007). The coefficient of friction of flaxseed is higher than karingda seed (Srthar and Das, 1996), Locust bean seed (Olajide and Ade-Omowaye, 1999), and hemp seed (Singh and Goswami, 1996) against plywood and galvanized iron and higher than hemp seed (Singh and Goswami, 1996), vetch seed (Yalçin and Özarslan, 2004), and cowpea seed (Yalçin, 2007) against stainless steel and aluminum sheet. The coefficient of friction of flaxseeds was found higher than those of other grains. Maybe the shape and high mucilage content of seed makes it difficult to roll on surfaces.

3.7 Angle of repose

The angle of repose (θ) increased linearly within the moisture content (M_c) range of 6.21%~16.29%. The relationship between angle of repose (θ) and moisture content (M_c) can be expressed as follows:

$$\theta = 0.7805\, M_c + 21.017$$

with a value for R^2 of 0.99.

The linear increase of angle of repose within increase of moisture content was found in other grains, for example, tef seed (Zewdu and Solomon, 2007), caper seed (Dursun and Dursun, 2005), and fenugreek seed (Altuntaş, Özgöz and Taşer, 2006).

The value is higher than sugerbeet seed (Dursun, Tuĝrul and Dursun, 2007), locust bean seed (Olajide and Ade-Omowaye, 1999), and hemp seed (Sacilik, Öztűrk and Keskin, 2003), lower than cumin seed (Singh and Goswami, 1996), sunflower seed (Gupta, Das, 1997), and similar to math gram (Nimakar, Mandwe and Dudhe, 2005).

3.8 Statistical analysis

All the *p* values were lower than 0.0001 in the experiment, it suggested that moisture content had a significant effect on properties of fibered flaxseed.

4. CONCLUSIONS

Length, width, thickness and geometric mean diameter of flaxseed increases within the increase of moisture content.

One thousand seed weight increases linearly within the increase of moisture content.

Bulk density decreased linearly from 726.783 to 611.872kg/m^3, and true density increases from 1165.265 to 1289.341kg/m^3 and porosity increase from 37.668% to 52.544% when moisture content increases from 6.21% to 16.29% (d. b.).

The static coefficient of friction against plywood was greatest, followed by aluminum sheet, galvanized iron, and stainless steel.

Angle of repose of flaxseed increased with the increase of moisture content.

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