Effect of moisture content on physical properties biology essay

Science, Biology

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ABSTRACT

The physical properties of fibered flaxseed were investigated within moisture content varying from 4. 62 to 18. 39%. 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 7. 31 to 8. 82g. The bulk density decreased from 726. 783 to 611. 872kg/m3, while the true density increased from 1165. 265 to 1289. 341kg/m3 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, aluminium 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. Key words: Flaxseed, Physical Properties, Moisture Content, Density, Angle of Repose

1. INTRODUCTION

Consumer interest in the relationship between diet and health has increased the demand for information about functional foods. Rapid advances in science and technology, increasing healthcare costs, changes in food laws affecting label and product claims, an aging population, and rising interest in attaining wellness through diet are among the factors fuelling populace interest in functional foods. Due to health promoting properties and excellent nutrient profile of flaxseed, it has been becoming a popular functional food product for incorporation in human diet. Flaxseed is being used extensively for the development of functional foods. The components of flaxseed, identified to exhibit the health benefits are fiber, lignans and linolenic acid (Omega-3 fatty acid). Moreover flaxseed is a good source of high quality protein, soluble fibers and phenolic compounds (Oomah, 2001). The seeds of flax or linseed (Linum usitatissimum L.) have been used for human consumption since ancient times. Flaxseed is recognized as nature's best vegetable source of Alpha Linolenic Acid, a beneficial omega-3 fatty acid, which several studies indicate has the ability to reduce risk for a host of adverse health conditions. The prospective health benefits of oil seeds such as flaxseed, especially in relation to cancer and cardiovascular disease has got more consideration by the nutrition workers and food scientists. 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 colour 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). With the increasing trends of flaxseed as functional foods, information regarding to physical properties of flaxseed is very important in the design for harvesting, transporting, cleaning, grading, packing, storing and processing for different foods. In order to design equipment for handling, conveying, separation, drying, aeration, storing and processing of flaxseed, it is essential to determine their physical properties as a function of moisture content. The properties of different types of grains and seeds have been determined by other researchers such as Dutta et al. (1988) for gram seed; Amin et al. (2004) and carman (1996) for lentil seed; 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. For instance, Bulk density, true density and porosity can be useful in sizing grain hoppers and storage facilities. 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. Keeping in view the health and nutritional benefits of the flaxseed and increasing use as functional food, the objective of study was carried out 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 flaxseeds used in this study were obtained from local market of Jaipur, Rajasthan, India and were used for all the experiments in this study. The seeds were cleaned manually by the removal of all foreign matter such as stones, dirt and 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 4. 62% dry basis (d. b.).

2. 2 Preparation of Samples

The experiments were conducted in the moisture range of 4. 62 – 18. 39% d. b. The amount of water to be added (Q) to the samples of the desired moisture contents were prepared by adding the amount of distilled water as calculated from the following equation:(1)Where, Q is the mass of distilled water to be added in kg, Wi is the initial mass of sample in kg, Mi is the initial moisture content of sample in % d. b. and Mf is the final (desired) moisture content of sample % d. b. The conditioned samples were packed separately in polythene bags and sealed tightly and stored in a refrigerator at a low temperature of at 5±1 °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 4. 62, 7. 24, 11. 12, 15. 63 and 18. 39%. Moisture content of the samples was determined by oven drying at 105±1°C for 24h. The seed moisture content range investigated 4. 62-18. 39% (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 (Singh and Goswami, 1996; Coskun et al., 2006). All the physical properties of the seeds were assessed at different moisture content with three replications. The following methods were used to determine some physical properties of flaxseeds.

2. 3 Methods

2. 3. 1 Size and Shape

One hundred seeds were randomly selected from sample according to the procedure described by Dutta et al. (1988). For each seed, three principal dimensions; length (L), width (W), and thickness (T) were measured using a digital vernier caliper to an accuracy of 0. 02 mm. At each moisture content, the dimensions of hundred different seeds were determined and mean value was taken. The geometric mean diameter (De), arithmetic mean diameter (Da), seed volume (V), and surface area (S) were calculated from the three principal dimensions according to the following relations (Jain & Bal, 1997): (2)(3)(4)(5)(6)

2. 3. 2 Thousand seed weight

Thousand seed weight was measured by counting 100 randomly selected seeds and weighing them using an electronic balance having an accuracy of 0. 001 g and then multiplied by 10 to give mass of 1000 seeds.

2. 3. 3 Bulk and true density

The bulk density was determined by filling an empty 250 ml graduated cylinder with the seed and then it was weighed (Mohsenin, 1970). The weight of the seeds was obtained by subtracting the weight of the cylinder from the weight of both the cylinder and seed. The volume occupied was saved. The process was replicated four times and the bulk density for each replication was calculated from the following relation:(7)Where: the ρb is the bulk density in kg/m3; Ws is the weight of the sample in kg; and Vs is the volume occupied by the sample in m3. The true density (ρt) was defined as the ratio between the mass of flaxseeds and the true volume of the seeds, and was determined using the toluene displacement method. Toluene was used instead of water because it is absorbed by seeds to a lesser extent. Fifty millilitre 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 was calculated from the values of bulk density and true density using the following relationship (Mohsenin, 1970): x 100 (8)Where, ε is porosity, ρt is the true density and ρb is the bulk density.

2. 3. 5 Angle of repose

The static angle of repose (θs) was determined by using the apparatus shown in Figure 1 consisting of plywood box of 140 x 160 x 35 cm and two plates: fixed and adjustable. The box was filled with the sample and then the adjustable plate was inclined gradually allowing the seeds to follow, assuming a natural slope (Tabatabaeefar, 2000; Heidabeigi et al., 2009). Fig. 1. Schematic of apparatus for determining angle of repose

2. 3. 6 Coefficient of static friction

The Coefficients of static friction of seeds on the four different surfaces including plywood, stainless steel, aluminium sheet, and galvanized iron were determined. The seeds were put on the surface with adjustable slips. Then, the surface was raised gradually until the seeds just start to slide down. Finally, the coefficient of friction was calculated from the following equation:(9)Where μ is the coefficient of friction and α is the angle of tilt in degree.

3. RESULTS AND DISCUSSION

3. 1 Effect of moisture content on one thousand seed weight

One thousand seed weight increased linearly from 7. 31 to 8. 82g when the moisture content was increased from 4. 62 to 18. 39% as shown in figure 2. The relationship between one thousand seed weight (W1000) and moisture content (MC) can be described as follows:+ 6. 7411 (R2 = 0. 9655)The results showed that the weight of one thousand flaxseed at different moisture content is lower than caper seed (Dursun and Dursun, 2005), similar to cumin seed (Singh and Goswami, 1996). F: Biotech ProjectJournalEffect of MOisture Content on Physical Properties of FlaxseedGraph1. jpg

Fig 2. Effect of moisture content on weight of 1000 seeds

3. 2 Effect of moisture content on seed axial dimensions

A summary of the dimensions of flaxseed is shown in Table 1. The length, width, arithmetic mean diameter and geometric mean diameter of seed increased from 5. 17 to 5. 46mm, 2. 53 to 2. 68mm, 2. 97 to 3. 12mm, 2. 53 to 2. 62mm respectively, with increase in moisture content from 4. 62 to 18. 39%. A linear and four nonlinear relationships were observed between moisture content and axial dimensions as follows:+ 5. 0596 (R2 = 0. 983)+

2. 4758 (R2 = 0. 982)+ + 1. 1311 (R2 = 0. 968)+ 2. 9164 (R2 = 0. 993)+ 2. 4802 (R2 = 0. 971)The thickness increased from 1. 21 to 1. 26mm with increase in the moisture content from 4. 62% to 11. 12% and decreased to 1. 23mm with further increase in moisture content to 18. 39%. Table 1. Means and standard deviations of the seed dimensions at different moisture content

Characteristics (mm)

Moisture Content (% d. b.)

Property4. 62%7. 24%11. 12%15. 63%18. 39%Length (L)5. 17±0. 68a5. 21±0. 265. 27±0. 425. 38±0. 475. 46±0. 56Width (W)2. 53±0. 522. 55±0. 312. 59±0. 642. 63±0. 562. 68±0. 24Thickness (T)1. 21±0. 181. 23±0. 621. 26±0. 231. 25±0. 341. 23±0. 14Arithmetic diameter (Da)2. 97±0. 582. 99±0. 663. 04±0. 343. 08±0. 263. 12±0. 44Geometric diameter (Dg)2. 51±0. 662. 54±0. 822. 58±0. 342. 61±0. 362. 62±0. 23The result indicates that the seeds expanded in length, width, thickness and geometric mean diameter within the moisture range 4. 62 to 18. 39%. 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, Öztũ̈rk 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. 3 Effect of moisture content on seed volume and surface area

The moisture dependence of seed volume and surface area for the moisture content ranging from 4. 62% to 18. 39% d. b. are shown in Fig. 3. These relationships were best fitted using nonlinear equation as follows:+ + 44. 564 (R2 = 0. 998)+ + 26. 728 (R2 = 0. 998)Seed volume and surface area increased by 17. 57% and 9. 59% respectively as moisture content increased from 6. 21% to 16. 29%. The nonlinear relationships might be due to the wide range of moisture content used (6. 21–16. 29%) which was selected to simulate the moisture content range for the flaxseed from harvest to storage stages. Similar studies, however, with smaller moisture content ranges showed that such nonlinear relationships may be needed to adequately predict the relation of volume and surface area and moisture content. Some of those studies were reported for millet (Baryeh, 2002), gram (Dutta et al., 1988), soybean (Deshpande et al., 1993), and popcorn (Karababa, 2006), Soybean (Tavakkoli et al., 2009). The ratio between volume and surface area is usually called the characteristic length. Characteristic length has important role in irregularly shaped objects. Some of its applications include determination of projected area of particles moving in turbulent air streams, which can be useful in designing of grain cleaners, separators, and pneumatic conveyors. As the ratio between surface area and volume increases, the rate of heat and mass transfer from seed increases, which affects several operations such as drying, cooling, and heating. F: Biotech

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Fig 3. Effect of moisture content on volume and surface of flaxseed

3. 4 Effect of moisture content on bulk density

The bulk density of the seeds at different moisture content decreased linearly from 702. 24 to 582. 37 kg/m3 within the moisture content range of 4. 62% to 18. 39% (d. b.). The relationship between bulk density (ρb) and moisture content (Mc) can be expressed as:+ 746. 65 (R2 = 0. 995)F: Biotech ProjectJournalEffect of MOisture Content on Physical Properties of FlaxseedGraphBulk density. jpg

Fig 4. Effect of moisture content on bulk density of flaxseed

The bulk density of flaxseed at different moisture content is higher than sunflower seed (Gupta, Das, 1997), hemp seed (Sacilik, Öztṻrk and Keskin, 2003). At the lowest moisture content (4. 62%) and the highest moisture content (18. 39%), 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. 5 Effect of moisture content on true density

The true density of seeds increases from 1124. 38 to 1242. 29 kg/m3 within the seed moisture content range of 4. 62-18. 39% (d. b.). The relationship of true density (ρt) and moisture content (Mc) can be expressed as:+ 1088. 8 (R^2 = 0. 978)F: Biotech ProjectJournalEffect of MOisture Content on Physical Properties of FlaxseedGraphTrue density. jpg

Fig 5. Effect of moisture content on true density of flaxseed

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).

3. 6 Effect of moisture content on porosity

The porosity of seeds was found to increase from 37. 544% to 53. 121% within moisture content range of 4. 62-18. 39% (d. b.). The relationship existed between porosity (ε) and seed moisture content (Mc) was found to be linear and can be expressed using the following equation with a coefficient of determination R^2= 0. 998:+ 32. 318 (R^2 = 0. 998)F: Biotech ProjectJournalEffect of MOisture Content on Physical Properties of FlaxseedGraphPorosity. jpg

Fig 6. Effect of moisture content on porosity of flaxseed

Higher porosity provides better aeration and water vapour diffusion during deep bed drying. 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, Öztűrk and Keskin, 2003).

3. 7 Effect of moisture content on angle of repose

The variation of the angle of repose, with seed moisture content is plotted in Figure 5. The angle of repose (θs) increased linearly from 23. 224º to 39. 148º within the moisture content (Mc) range of 4. 62%-18. 39%. The relationship between angle of repose (θs) and moisture content (Mc) can be expressed as follows:+ 18. 329 (R2 = 0. 988)F: Biotech ProjectJournalEffect of MOisture Content on Physical Properties of FlaxseedGraphAngle of repose. jpg

Fig 7. Effect of moisture content on angle of repose of flaxseed

The linear increase of angle of repose within increase of moisture content was found in other grains, for example, 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 Effect of moisture content on static coefficient of friction

The static coefficient of friction of seeds was obtained experimentally on four surfaces within moisture content range of 4. 62-18. 39% (d. b.) was shown in Fig 8. It indicted that the aluminium sheet had the highest static coefficient of friction (0. 446) at the lowest moisture content (4. 62%) followed galvanized iron (0. 438), plywood (0. 432), and stainless steel (0. 427). At the highest moisture content (18. 39%), plywood (0. 961) had the highest coefficient of friction followed by aluminium sheet (0. 946), stainless steel (0. 935), and galvanized iron (0. 928), 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 (Mc) were expressed as follows:+ 0. 2575 (R2 = 0. 993)+ 0. 2404 (R2 = 0. 994)+ 0. 2890 (R2 = 0. 997)+ 0. 2575 (R2 = 0. 995)Where: µp, µs, µa, and µg is static coefficient of friction against plywood, stainless steel, aluminium sheet, and galvanized iron, with values of coefficient of determination R2 of 0. 993, 0. 994, 0. 997 and 0. 995 respectively. F: Biotech ProjectJournalEffect of MOisture Content on Physical Properties of FlaxseedGraphStatic coeff of friction. jpg

Fig 8. Effect of moisture content on the static coefficient of friction of flaxseed against various surfaces

Table 2. Comparison of the static coefficient of friction of flaxseed against various surfaces with respect to moisture content

4. 62 (Lowest Moisture Content, % d. b.)

μa > μg > μp > μs

18. 39 (Highest Moisture Content, % d. b.)

μp > μa > μs > μg

The similar results for plywood, galvanized iron, stainless steel and aluminium 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 aluminium 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. Table 3. Means of physical properties of flaxseed at different moisture content

M. C. (% d. b.)

Length

(L, mm)

Width

(W, mm)

Thickness

(T, mm)

True

Density

(ρt, Kg/m3)

Bulk

Density

(ρb, Kg/m3)

Angle of

Repose

(AOR, °)

Coefficient of Static Friction

(μ)

μp

μs

μa

µg

4. 62%

5. 17

2. 53

1. 21

702. 24

1124. 38

23. 224

0. 432

0. 427

0. 446

0. 438

7. 24%

5. 21

2. 55

1. 23

684. 32

1146. 62

26. 944

0. 532

0. 512

0. 554

0. 529

11. 12%

5. 27

2. 59

1. 26

653. 46

1194. 72

30. 026

0. 664

0. 634

0. 684

0. 636

15. 63%

5. 38

2. 63

1. 25

608. 24

1214. 26

34. 678

0. 812

0. 846

0. 828

0. 816

18. 39%

5. 46

2. 68

1. 23

582. 37

1242. 29

39. 148

0. 961

0. 935

0. 946

0. 928

4. CONCLUSIONS

The physical properties of flaxseed determined as a function of moisture content varied significantly with increased in moisture content. For flaxseeds, the conclusions in the moisture content range of 4. 62% to 18. 39% d. b. are as follows: Due to change in moisture content from from 4. 62 to 18. 39% d. b. the average length, width , geometric mean diameter and arithmetic mean diameters of flaxseed increased from , 5. 17 to 5. 46mm, 2. 53 to 2. 68mm, and 2. 51 to 2. 62mm, 2. 97 to 3. 12 mm, respectively while the thickness increased from 1. 21 to 1. 26mm with increase in the moisture content from 4. 62% to 11. 12% and decreased to 1. 23mm with further increase in moisture content to 18. 39%. The values of thousand flaxseed weight, surface area and volume increased from 7. 31 to 8. 82 g, 45. 15 to 50. 47 mm2, 27. 21 to 32. 28 mm3, respectively, as the moisture content increased from 4. 62 to 18. 39% d. b. Bulk density decreased linearly from 702. 24 to 582. 37 kg/m3, and true density increases from 1124. 38 to 1242. 29 kg/m3 and porosity increase from 37. 544% to 53. 121% when moisture content increases from 6. 21% to 16. 29% (d. b.). The angle of repose of flaxseed increased from 23. 224º to 39. 148º when moisture content increases from 4. 62% to 18. 39% (d. b.). The static coefficient of friction was in the range of 0. 427 to 0. 961 over different material surfaces due to change in moisture content from 4. 62 to 18. 39% (d. b.). The static coefficient of friction against aluminium sheet had the highest static coefficient of friction (0. 446) at the lowest moisture content (4. 62%) followed galvanized iron (0. 438), plywood (0. 432), and stainless steel (0. 427)while at the highest moisture content (18. 39%), plywood (0. 961) had the highest coefficient of friction followed by aluminium sheet (0. 946), stainless steel (0. 935), and galvanized iron (0. 928), respectively.

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