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*Note*

# Physical and chemical properties of flaxseed

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A b s t r a c t. Physical and chemical properties of flaxseed were studied as a function of moisture content. The geometric properties increased with increasing moisture content. The bulk density, rupture force, deformation and energy absorbed decreased linearly while true density, porosity, thousand seed mass, angle of repose and static coefficient of friction increased linearly with increasing moisture content.

K e y w o r d s: flaxseed, physical properties, chemical properties

## INTRODUCTION

Flax (*Linum usitatissimum* L.), a member of the *Linaceae* family, is one of the most important oilseed crops for industrial as well as food and feed purposes. Flaxseed has been used as a human food since ancient times. Nowadays flaxseed is gaining popularity in the food sector for its functional properties, since it is a rich source of essential fatty acids, omega-6 essential fatty acids, lignans, vitamins and minerals. Desired health benefits have led to the development of a wide range of flaxseed fortified foods including breakfast cereals, snack foods, and soups (Daun *et al*., 2003).

The aim of the present study was to investigate the physical and chemical properties of flaxseed (cv. Neelam) as a function of water content.

## MATERIALS AND METHODS

Flaxseed cv. Neelam was procured from CSAUA and T Kanpur, Uttar Pradesh, India. The seeds were cleaned manually. The moisture content of seed was determined using the hot air oven method (AOAC, 2000). The desired quantity of distilled water to be added, or moisture to be evaporated (seed to be dried) was calculated by using standard formula and the conditioned seeds were mixed thoroughly, packed in airtight containers and kept at 5±1°C in a refrigerator for 15 days to distribute moisture uniformly throughout the samples. The samples were brought to room temperature (30±2ºC) to determine the actual moisture content present in the sample prior to conducting the experiments for determination of its properties in triplicate. The average values of moisture were found to be 3.95, 6.99, 10.68, 13.73, and 17.21% d.b.

For the size and shape of the flaxseed 100 seeds were randomly selected and for each individual seed, length, width and thickness were measured by using a digital calliper (0.01 mm). These values were used to calculate the geometric mean diameter, sphericity, surface area and unit volume of flaxseed by using standard relationships (Mohsenin, 1980).

Bulk density was determined by filling a 250 ml cylinder with seeds from a set height, tapping twice and then weighing the contents. True density was measured by using the toluene displacement method. The porosity of seed was calculated from the values of true density and bulk density using an established relationship (Mohsenin, 1980). 1 000 seeds mass (g) was determined by randomly selecting 100 seeds, weighing them and multiplying the result by 10. The estimation of bulk density, true density and 1 000 seeds mass was carried out in 5 replicates and average values were reported.

The angle of repose ($\theta$) was calculated from the height and diameter of the naturally formed heap of the seeds on a circular plate (Kingsley *et al*., 2006) in 3 replicates. The coefficient of static friction ($\mu$) was determined by using a laboratory set up on plywood, galvanized iron, aluminium and mild steel sheet (3 replicates).

Mechanical properties such as rupture force, energy absorbed and deformation of seeds were determined using a Texture Analyser (TA-Hdi, Stable Microsystem, UK),

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equipped with a 500 N load cell and a graph recorder. The test speed and post-test speed of 1and 2 mm $s^{-1}$ was used with a distance of 30% with SMS P/5 probe. The individual seed was loaded between the probe and the base plate and compressed at preset conditions until rupture occurred as denoted by the bio-yield point (N) in the force-deformation curve. The energy absorbed (kJ) was calculated by determining the area under the force-deformation curve up to the seed rupture-point (Kingsley *et al*., 2006). Deformation (strain) was taken as change in dimensions/original dimensions of the seed (20 replicates). The chemical properties of flaxseed were determined using standard methods (AOAC, 2000) at moisture content of 6.99% d.b. Omega-3 fatty acid as alpha-linolenic acid content was determined by using gas liquid chromatography.

Data were analyzed as per one factor analysis of variance (ANOVA) using LSD of AgRes software statistical package. Regression analysis was carried out using Microsoft Excel-2003 software.

## RESULTS AND DISCUSSION

The geometric properties of flaxseed *cv. Neelam*, along with means and standard deviations, in the moisture range of 3.95 to 17.21% d.b., are presented in Table 1. All geometric properties such as length, width, thickness, geometric mean diameter, surface area, sphericity and unit volume, increased linearly with increasing moisture content. The average length, width, thickness and geometric mean diameter increased linearly from 5.75 to 5.80 mm ($R^2$ = 0.8887), 2.85 to 2.92 mm ($R^2$ = 0.8167), 0.92 to 0.97 mm ($R^2$ = 0.9358) and 2.46 to 2.54 mm ($R^2$ = 0.9790), respectively, with increasing moisture content. The increase in the dimensions are attributed to expansion or swelling as a result of moisture uptake in the intracellular spaces within the seeds. It was observed that the increase in length and width was statistically non-significant ($p<0.05$), whereas thickness increased significantly as moisture content increased. Selvi *et al*. (2006) reported significant increase in length, width and thickness of flaxseed ($p<0.01$) at moisture content of 8.25 to 22.25% d.b. where flaxseeds expanded more in thickness in comparison to its other two principal axes. The geometric mean diameter of flaxseed was lower than that of sunflower and guna seeds and higher than that of sesame (Tunde-Akintunde and Akintunde, 2004). The sphericity increased from 42.92 to 43.71% ($R^2$ = 0.8351) as the moisture increased linearly with increasing moisture content. A similar trend of increase in sphericity with increasing moisture content was observed for rapeseed, cottonseed and flaxseed (Izli *et al*., 2009; Ozarslan, 2002; Selvi *et al*., 2006). The surface area and unit volume of seeds increased linearly from 19.12 to 20.25 $mm^2$ ($R^2$ = 0.9662) and 7.93 to 8.64 $mm^3$ ($R^2$ = 0.9686), respectively.

The bulk density decreased from 680 to 579 kg $m^{-3}$ linearly ($R^2$=0.7100), whereas true density increased from 1067 to 1147 kg $m^{-3}$ ($R^2$ = 0.9622) with increasing moisture content ($p<0.05$) (Table 2). The decrease in bulk density of

**T a b l e 1.** Geometric properties of flaxseed cv. Neelam at different moisture content

| Moisture content (%, d.b.) | Length (mm) | Width (mm) | Thickness (mm) | Geometric mean diameter (mm) | Sphericity (%) | Surface area ($mm^2$) | Unit vol. ($mm^3$) |
|---|---|---|---|---|---|---|---|
| 3.95 | 5.75 (0.23) | 2.85 (0.17) | 0.92bc (0.13) | 2.46 (0.14) | 42.92 (2.53) | 19.12 (2.17) | 7.93bc (1.35) |
| 6.99 | 5.76 (0.25) | 2.89 (0.24) | 0.92c (0.16) | 2.47 (0.22) | 42.99 (3.78) | 19.32 (2.95) | 8.07c (1.67) |
| 10.68 | 5.76 (0.25) | 2.91 (0.21) | 0.95abc (0.13) | 2.5 (0.15) | 43.61 (2.23) | 19.86 (2.36) | 8.40abc (1.50) |
| 13.73 | 5.79 (0.27) | 2.91 (0.15) | 0.96ab (0.15) | 2.51 (0.18) | 43.50 (3.39) | 19.94 (2.50) | 8.46ab (1.44) |
| 17.21 | 5.80 (0.24) | 2.92 (0.14) | 0.97a (0.13) | 2.54 (0.13) | 43.71 (2.21) | 20.25 (2.14) | 8.64a (1.36) |

Values in the same columns followed by different letters (a-e) are significant ($p<0.05$). Figures in parenthesis are standard deviation.

**T a b l e 2.** Densities, porosity and 1 000 seeds mass of flaxseed cv. Neelam at different moisture content

| Moisture content (%, d.b.) | True density (kg $m^{-3}$) | Bulk density (kg $m^{-3}$) | Porosity (%) | 1 000 seed mass (g) |
|---|---|---|---|---|
| 3.95 | 1067d (4.43) | 680a (2.93) | 36.32e (0.32) | 7.35c (0.02) |
| 6.99 | 1084c (7.26) | 676a (5.26) | 37.65d (0.46) | 7.58c (0.09) |
| 10.68 | 1114b (3.74) | 660b (10.44) | 40.79c (1.07) | 9.38b (0.51) |
| 13.73 | 1142a (15.72) | 660b (2.59) | 42.27b (0.90) | 9.91b (0.16) |
| 17.21 | 1147a (5.39) | 579c (3.24) | 49.50a (0.44) | 10.67a (0.46) |

Explanations as in Table 1.

**T a b l e 3.** Frictional properties of flaxseed cv. Neelam at different moisture content

| Moisture content (%, d.b.) | Angle of repose | Coefficient of friction | | | |
|---|---|---|---|---|---|
| | | Plywood | Aluminium | Galvanized iron | Mild steel |
| 3.95 | 25.62d (0.63) | 0.416c (0.01) | 0.369e (0.01) | 0.363e (0.01) | 0.490e (0.01) |
| 6.99 | 26.04d (0.35) | 0.487bc (0.01) | 0.441d (0.01) | 0.530d (0.01) | 0.515d (0.01) |
| 10.68 | 30.18c (0.32) | 0.666a (0.01) | 0.633b (0.01) | 0.570c (0.01) | 0.732b (0.01) |
| 13.73 | 37.5b (1.17) | 0.593ab (0.01) | 0.613c (0.01) | 0.656b (0.01) | 0.696c (0.01) |
| 17.21 | 39.9a (0.55) | 0.715a (0.01) | 0.739a (0.01) | 0.772a (0.01) | 0.803a (0.01) |

Explanations as in Table 1.

flaxseed with increase in moisture content indicated that the increase in the expansion of bulk volume is greater than the increase in mass gain. The increase in true density of flaxseed with increase in moisture content indicated that the increase in mass gain in the sample is greater than the increase in the volume of seed. Similar trends in densities have been reported for flaxseed (Selvi *et al*., 2006) and lentil seeds (Amin *et al*., 2004). The porosity increased linearly from 36.32 to 49.50% ($R^2$=0.9079) with increase in moisture content from 3.95 to 17.21%. The 1 000 seeds mass increased linearly from 7.35 to 10.67 g ($R^2$ = 0.9570) with increasing moisture content, the increase was significant ($p<0.05$) whereas values at 3.95 and 6.99% d.b. were not significantly different. Similar trends have been shown for rapeseed and flaxseed (Coşkuner and Karababa, 2007; Izli *et al*., 2009).

The angle of repose and the coefficient of static friction are presented in Table 3. The angle of repose increased linearly from 25.62 to 39.90° ($R^2$ = 0.9308) with increasing moisture content from 3.95 to 17.21% d.b. ($p\leq0.05$). Increasing trends were reported by Mohsenin (1980) for the most of the biological materials. The increase in angle of repose with moisture content may be due to an increase in the internal friction with the moisture content. Coşkuner and Karababa (2007) reported an increase of the angle of repose in flaxseed from 21.6 to 33.4° with a seed moisture content range of 6.09 to 16.81%, whereas Selvi *et al*. (2006) reported an increase in the angle of repose from 21.59 to 26.85° in a moisture range of 8.25 to 22.25% d.b. The coefficient of static friction increased linearly ($p<0.05$) in the ranges: 0.416-0.715 ($R^2$= 0.8246), 0.369-0.739 ($R^2$= 0.9278), 0.363-0.772 ($R^2$= 0.9580) and 0.490-0.803 ($R^2$= 0.8737) for plywood, aluminium, galvanized iron and mild steel sheet surfaces, respectively. This is so because increased moisture content may result in an increase in the adhesion characteristics and roughness of the surface of flaxseed (Bagherpour *et al*., 2010; Coşkuner and Karababa, 2007; Kingsley *et al*., 2006).

The increase of moisture content seeds caused of the decrease of rupture force, deformation and energy absorbed decreased in quadratic manner in the ranges 42.27-36.04 N ($R^2$ =0.9845), 0.305-0.276 mm ($R^2$=0.9166) ($p<0.05$) and 12.85-9.96 kJ ($R^2$=0.9913) ($p<0.05$), respectively (Table 4). Similar findings were reported for dried pomegranate seeds (Kingsley *et al*., 2006).

The chemical properties of flaxseed are presented in Table 5. At the initial moisture content (6.99% d.b.), it had 21.76% protein, 42.41% fat, and 26.11% total carbohydrates. These are in accordance with 37.15% lipids, 20.3% protein and 28.9% carbohydrates (Gopalan *et al*., 2007). The ash content and crude fibre were 4 and 5.71%, respectively, which are in agreement with the results reported by Mazza (2008). The calcium and iron contents were 128.63 and 9.22 mg 100 $g^{-1}$. The omega-3 fatty acid content was 54.66%, which was higher than the range of omega-3 fatty acid (45-52%).

**T a b l e 4.** Mechanical properties of flaxseed cv. Neelam at different moisture content

| Moisture content (%, d.b.) | Rupture force (N) | Deformation (mm) | Energy absorbed (kJ) |
|---|---|---|---|
| 3.95 | 42.27a (7.44) | 0.305a (0.03) | 12.85a (2.62) |
| 6.99 | 41.71a (6.92) | 0.302a (0.05) | 12.57a (2.68) |
| 10.68 | 39.41ab (3.72) | 0.296ab (0.02) | 11.66ab (1.14) |
| 13.73 | 38.56ab (8.93) | 0.278b (0.04) | 10.76bc (3.17) |
| 17.21 | 36.04b (5.63) | 0.276b (0.04) | 9.96c (2.21) |

Explanations as in Table 1.

**T a b l e 5.** Chemical properties of flaxseed cv. Neelam at 6.99% d.b. moisture content

| Parameters | Value |
|---|---|
| Moisture (%) | 6.99 (0.24) |
| Protein (%) | 21.76 (0.58) |
| Fat (%) | 42.41(1.01) |
| Crude fibre (%) | 5.71 (0.08) |
| Crude fibre (fat free basis) (%) | 10.06 (0.17) |
| Total carbohydrates* (%) | 26.11 (0.80) |
| Ash (%) | 4.00 (0.25) |
| Calcium (mg 100 $g^{-1}$) | 128.63 (2.23) |
| Iron (mg 100 $g^{-1}$) | 9.22 (0.32) |
| Omega-3 fatty acid (%) | 54.66 (0.22) |

Figures in parenthesis are standard deviation, *by difference.

## CONCLUSIONS

1. The average length, width, thickness, geometric mean diameter, surface area and unit volume of flaxseeds cv. Neelam increased linearly with increasing moisture content from 3.95 to 17.21% d.b.

2. True density, porosity and angle of repose increased linearly whereas bulk density decreased linearly with increasing moisture content.

3. Coefficients of static friction increased linearly plywood, aluminium, galvanized iron, and mild steel surfaces as the moisture content increased.

4. The rupture force, deformation and energy absorbed decreased linearly with increasing moisture content.

5. The moisture content, values of protein, fat, crude fibre, total carbohydrates and omega-3 fatty acid of flaxseed (cv. Neelan) were 21.76, 42.41, 5.71, 26.11 and 54.66 at 6.99% d.b., respectively.

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