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Studies on Some Physical and Engineering Properties of Linseed

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ABSTRACT: The engineering properties of linseed were investigated for three varieties i.e. Neelam, Shekhar, and Sheela within the moisture content range of 8 to 14% (d.b). Based on statistical analysis there is significant effect of variety and moisture content on all physical and engineering properties of linseed. The linear dimensions i.e. length, width, thickness and geometric mean diameter (GMD) of linseed seed increased with increase in moisture content for all three varieties. However, the highest length, width and thickness were observed for the Neelam variety of linseed as 5.53mm, 2.92mm 0.90 mm and 2.56 mm respectively. However, the highest surface area, sphericity, volume and 1000 grain weight were observed for the Neelam Variety of linseed as 21.51mm^2, 8.86mm^3 10.59 g respectively at moisture content of 14 %. The highest true density, porosity and lowest value of bulk density were observed for the Neelam Variety of linseed as 1128.56 kg/m^3, 41.16 and 664.03kg/m^3 respectively. The highest angle of repose, coefficient of friction at GI sheet, MS sheet and plywood surface, terminal velocity were observed 23.19°, 0.41, 0.47, 0.53, and 3.14m/s respectively at 14% moisture content. The mean value of rupture force for linseed seed, linseed capsule, and linseed stalk tip were observed 46.25 N, 5.99 N and 8.08 N respectively.

Keywords: Linseed, engineering properties, Physical properties.

INTRODUCTION

Linseed (*Linum usitatissimum* L.) is a major oilseed crop grown in central India. It is locally known as Jawas, *Alashi* or *Alsi*. It has been cultivated since ancient time for flax (fiber) and seed production. Every portion of the linseed plant is used economically, either directly or after processing. Linseed has received a lot of attention in recent years due to its nutritional content, which has a good effect on disease prevention by giving health-promoting components like alfalinolenic acid, lignin, and polysaccharides essential amino acids, carbohydrates, vitamins, minerals, and crude fiber. Linseed is the best herbal source of ω-3 and ω -6 fatty acids. Diets high in dietary fiber can lower the risk of heart disease, diabetes, colorectal, cancer, obesity, and inflammation (Bozan and Temelli, 2008). India is one of the world's major producers of linseed. India contributed about 10.81% and 5.31 % to world area and production. Linseed is currently grown on approximately 2.63 million hectares adding 1.26 million tones to the country's annual oilseed production. The average productivity of linseed is 477 kg/ha (Agashe *et al.,* 2018). Madhya Pradesh, Uttar Pradesh, Chhattisgarh, Bihar, Rajasthan, Odisha and Karnataka are the major linseed growing state in India. In terms of area and production of linseed, India ranks third in the globe.

MATERIALS AND METHODS

The linseed of three popular variety were collected in adequate quantity from Agronomy department IGKV Raipur, Chhattisgarh, India. Seed were cleaned manually to remove all foreign material such as dust, dirt and broken and immature seeds. The initial moisture content of seed was determined by using the standard hot air oven method using the following formula (AACC, 1995).

$$MC(\%) = \frac{W_2-W_3}{W_3-W_1} \times 100 \qquad (1)$$

Where, MC= Moisture content on dry basis, %; W_1= Initial weight of the bowl, g; W_2 = sample weight before drying + bowl weight, g; W_3 = sample weight after drying + bowl weight, g.

Seed sample of desired moisture content levels were prepared by adding calculated amount of distilled water by using following equation and mixed thoroughly (Sacilink *et al*., 2002)

$$Q = W_i \times \left(\frac{m_f-m_i}{100-m_f}\right) \qquad (2)$$

Where, Q = Weight of water to be added, g; W_i = Initial weight of seed sample, g; m_i = Initial moisture content of seed sample (% db); and m_f = Final moisture content of seed sample (% db).

A. Linear dimension of seed

To determine the size and shape of linseed, length, breadth and thickness of randomly selected 10 seeds of each variety were measured by using a digital Vernier calliper with least count reading 0.01 mm and its average was recorded.

$$GMD = (LBT)^{\frac{1}{3}} \quad (3)$$

B. Surface area

The surface area (S) was calculated by using the expression given by (Singh *et al.*, 2013).

$$S = \pi(GMD)^2 \quad (4)$$

C. Sphericity

Sphericity is defined as the ratio of the surface area of the sphere having the same volume as that of the grain to the surface area of the grain and it was determined using following formula (Mohsenin, 1986).

$$\emptyset = \frac{(LBT)^{\frac{1}{3}}}{L} \quad (5)$$

Where, L = Length of seed, mm; B = Breadth of seed, mm; and T = Thickness of seed, mm.

D. Volume (V)

The volume of the grain was determined by taking the dimensions of seed of three axes length, width and thickness and then volume was estimated using the following relationship as described by Mohsenin (1986)

$$V = \frac{\pi LBT}{6} \quad (6)$$

Where, V = Volume, mm^3; L= Length of seed, mm; B= Breadth of seed, mm; T= Thickness of seed, mm; and π = constant (22/7).

E. Thousand grain weight (M1000)

One thousand randomly selected grains of test samples at various moisture levels were collected and weighed on electronic balance having a least count of 0.01 g. this magnitude is termed as the thousand-grain weight specific to the grain. The procedure described in IS: 4333 (part IV)-1986 was adopted. Average of ten replications have been considered and reported as a 1000 grain weight of sample (Anonymous 2002).

F. Bulk density

The bulk density of seed is the ratio of its mass to total volume. It was determined by using standard test weight procedure by filling a 500ml container with seeds from a height of about 15cm at constant rate, striking the top level and weighing the contents. Bulk density was then calculated as the ratio between the kernels weight and the volume of the cylinder (Akaaimo and Raji, 2006; Mwithiga and Sifuna, 2006).

$$Pb = \frac{W_s}{V_s} \quad (7)$$

Where, P_b = Bulk density in kg/m^3; W_s = Weight of the sample in kg; and

V_s = Volume occupied by the sample, m^3.

G. True density

The true density defined as the ratio of mass of the sample to its true volume, was determined using the toluene (C_7H_8) displacement method. 50 millilitres of toluene were placed in a 100ml graduated measuring cylinder and 5g seeds were immersed in the toluene (Mwithiga and Sifuna, 2006; Oyelade *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

$$TD = \frac{W_s}{T_{vs}} \quad (8)$$

Where, TD = True density, kg/m^3; W_s= Weight of seed, kg; and

T_{vs} = True volume of seed, m^3.

H. Coefficient of static friction

The static coefficient of friction may be defined as the friction force acting between surfaces of contact at rest with respect to each other. The coefficient of static friction apparatus consists of a horizontal plane and bottomless open container and the container was tied with a cord passing over a frictionless pulley attached to a pan. Static coefficient of friction was determined with respect to four surfaces: plywood, stainless steel, glass, and galvanized iron. Known weight of linseed was taken in the container. The weights were added in the pan and at the instant at which the pan weight exceed the sample weight and friction; the container start to slide on selected surface the static coefficient of friction was calculated using the equation suggested by Sahay and Singh, (1994); Niveditha *et al.*, (2013)

$$\mu = \frac{F}{N} \quad (9)$$

Where, μ = Coefficient of friction;

F = Friction force (force applied); and

N = Normal force (weight of the linseed sample).

I. Terminal velocity

The terminal velocity is defined as the velocity of air at which the grain is neither blown upward nor fallen downward; rather remains in the suspended state. The terminal velocities of linseed at different moisture contents were measured using an air column device. For each experiment, a sample was dropped into an air stream from the top of the air column. Then airflow rate was gradually increased until the seed became suspended in the air stream. The air velocity which kept the seed in suspension was measured using a pivot tube in conjunction with a micro manometer (Gupta and Das, 1997; Sacilink *et al*., 2002).

J. Angle of repose

The angle of repose is the angle with horizontal at which the material will stand when piled. To determine angle of repose, a box measuring 950mm × 100mm × 150mm, having an open ended cylinder of 70mm diameter and 45mm height of cone with removable front panel was used. The box was filled with the linseeds from until the cone was formed on circular plate and the front panel was quickly removed, allowing the seeds to flow to their natural slope. The height of the cone was recorded by using scale of 0-1 cm precision. The angle of repose (θ) was calculated using the following formula

$$\theta = \tan^{-1}\left(\frac{2H}{D}\right) \quad (10)$$

Where, H = Height of the cone, cm; and D = Diameter of cone, cm.

K. Rupture force

The experiment was carried out to find the rupture force of linseed seed, linseed capsule and stalk. The texture analyzer (TW+Di) was used for determination of force. The texture analyzer consisted of two primary components: hardware (load cell with a platform to hold sample and moving head for holding probe) and software (Texture Expert) for recording & calculating the test results. Before performing the tests, the machine was calibrated for load and distance for each type of test. The load calibration was done to check whether the load cell was accurate in sensing the force imposed over the sample of seed, capsule and stalk. Calibrating 50 g were suspended on the crosshead and selected the desired option under T.A. settings. Similarly, calibrated the movement of the cross ensure the compliance of the set deformation (strain) of the sample. After calibrating the texture analyzer, a sample of linseed capsule was placed on the platform. Different probes were used for different tests as per settings to generate the force-time curves. The force required to rupture or deform was abstracted from the graph shown and procedure repeated for 5 times to get the average mean value. Similar process was carried out for seed and stalk (Kingsley *et al*., 2006).

L. Statistical analysis

The interaction between the variety and moisture content was analysed by 2 factor split plot design(SPD) having variety as main plot and moisture content as sub plot with 4 replication.

RESULT AND DISCUSSIONS

A. Physical Properties of Linseed Capsule

The parameters under physical property of linseed capsule includes, no. of capsule per plant, no of seed per capsule, length, width and thickness of capsule and geometric mean diameter (GMD). The results on the physical properties of linseed capsule have been presented in Table 1. It was found that 37.5 number of capsules were found per plant. The number of seeds per capsules was observed to be 9.59 with a range of 9.23 to 9.75. Whereas, length, width and thickness of linseed were observed as 7.79, 6.57 and 6.49 mm respectively. The geometric mean diameter was ranges from 6.48 to 7.16 mm. The variations among the samples are not more. Similar type of observation were found by Maurya *et al*., (2017).

Table 1: Physical properties of linseed capsule (N = 05).

Particular	**No. of linseed capsule per plant**	**No of seed per capsule**	**Length, mm**	**Width, mm**	**Thickness, mm**	**GMD, mm**
Mean	37.50	9.59	7.79	6.57	6.49	6.91
Range	36.23-38.34	9.23- 9.75	7.58-7.94	5.98-7.00	5.91-6.96	6.48-7.16
SD (σ)	0.77	0.21	0.14	0.38	0.41	0.27
CV	0.02	0.02	0.02	0.06	0.06	0.04

B. Effect of varieties and moisture content on linear dimension and GMD

The results on linear dimensions i.*e*. length breadth and thickness of three varieties of linseed seed *i.e.* Neelam, Shekhar and Sheela were found out within the moisture range of 8% to 14%. It was observed that there is significant difference at 1% level in between the varieties on linear dimension (length, breadth, thickness). It was found highest length (5.41mm), breadth (2.86mm) for Neelam variety whereas highest Thickness (0.97 mm) was found for both Neelam and Shekhar variety. The lowest linear dimensions were observed in case of Sheela variety. It was also observed that moisture content also plays a vital role on linear dimension. It was observed length (5.19mm), breadth (2.68) and thickness (1.00 mm) in case of moisture content of 14% which were significantly highest (α=0.01). The observation of an increased in linear dimension and average diameter of linseed with regards to increase in moisture content agree with the findings reported by Bhishe *et al.*, (2013); Wang *et al*., (2007). It was observed that there is significant difference at 1% level in between the varieties on Geometric mean diameter (GMD). It was found highest (2.44mm) for Neelam variety and lowest in case of Sheela variety. It was also observed that moisture content also plays a vital role on GMD. It was observed 2.39 mm in case of moisture content of 14% which was significantly highest (α=0.01).

Table 2: Effect of varieties and moisture content on GMD for linseed.

Moisture content (%)	**Length(mm)**			**Width (mm)**			**Thickness (mm)**			**GMD (mm)**		
	V1	V2	V3	V1	V2	V3	V1	V2	V3	V1	V2	V3
M1(8.00)	5.27	4.53	4.58	2.77	2.50	2.37	0.90	0.93	0.84	2.34	2.17	2.07
M2(10.00)	5.38	4.66	4.73	2.86	2.59	2.39	0.92	0.96	0.88	2.39	2.24	2.13
M3(12.00)	5.49	4.84	4.90	2.89	2.65	2.40	0.98	0.98	0.89	2.47	2.30	2.17
M4 (14.00)	5.53	5.01	5.03	2.92	2.70	2.42	0.90	0.93	0.84	2.56	2.39	2.21
Mean	5.41**	4.76	4.81	2.86	2.61	2.40	0.97	0.97	0.88	2.44**	2.27	2.15
CD	0.08			0.03			0.02			0.02		

Where, V1 = Neelam, V2 = Shekhar, V3 = Sheela, ** = significant at 1% level of significance.

C. Effect of varieties and moisture content on surface area, sphericity, volume and thousand grain weight (TGW) for linseed

It was observed that there is significant difference at 1% level in between the varieties on surface area. It was found highest (18.74mm^2) for Neelam variety and lowest in case of Sheela variety. It was also observed that moisture content also plays a vital role on surface area. It was observed 17.93 mm^2 in case of moisture content of 14% which was significantly highest (α=0.01). It was observed that there is significant difference at 1% level in between the varieties on sphericity. It was found highest (48%) for Shekhar variety. It was also observed that there is no significant difference at 1% level in between the moisture content on surface area.

Table 3: Effect of varieties and moisture content on surface area, sphericity, volume and TGW for linseed.

Moisture content (%)	Surface area (mm^2)			Sphericity			Volume(mm^3)			TGW(g)		
	V1	V2	V3	V1	V2	V3	V1	V2	V3	V1	V2	V3
M1(8.00)	17.23	14.84	13.51	0.45	0.48	0.45	6.91	5.51	4.78	8.83	8.20	6.52
M2(10.00)	18.00	15.75	14.34	0.45	0.48	0.45	7.37	6.04	5.21	9.19	8.30	6.93
M3(12.00)	19.22	16.62	14.86	0.45	0.48	0.44	8.14	6.55	5.51	9.73	8.57	7.16
M4(14.00)	20.51	17.88	15.40	0.46	0.48	0.44	8.86	7.31	5.83	10.59	8.71	7.59
Mean	18.74**	16.27	14.53	0.45	0.48**	0.45	7.82**	6.35	5.33	9.58**	8.45	7.05
CD	0.29			0.01			0.19			0.38		

It was observed that there is significant difference at 1% level in between the varieties on volume. It was found highest (7.82mm^3) for Neelam variety and lowest in case of Sheela variety. It was also observed that moisture content also plays a vital role on volume. It was observed 7.34 mm^3 in case of moisture content of 14% which was significantly highest (α=0.01).

It was observed that there is significant difference at 1% level in between the varieties on thousand grain weight. It was found highest (9.58g) for Neelam variety and lowest in case of Sheela variety. It was also observed that moisture content also plays a vital role on weight of 1000 grains. It was observed 8.96g in case of moisture content of 14% which was significantly highest (α=0.01). The observation of an increased in 1000 grain weight of linseed with regards to increase in moisture content agree with the findings reported by Coskuner and Karbaba (2007); Bhishe *et al.,* (2013); Wang *et al*., (2007).

D. Effect of varieties and moisture content on bulk density, true density and porosity for linseed

It was observed that there is significant difference at 1% level in between the varieties on bulk density. It was found highest (722.18.kg/m^3) for Sheela variety and lowest in case of Neelam variety. It was also observed that moisture content also plays a vital role on bulk density. It was observed 716.06 kg/m^3 in case of moisture content of 8 % which was significantly highest (α=0.01). Bulk density decreased with increasing moisture content. The observation of an increased in bulk density of linseed with regards to increase in moisture content agree with the findings reported by Coskuner and Karbaba (2007); Selvi *et al.,* (2006).

Table 4: Effect of varieties and moisture content on bulk density for linseed.

Moisture content (%)	Bulk density (kg/m^3)			True density (kg/m^3)			Porosity		
	V1	**V2**	**V3**	**V1**	**V2**	**V3**	**V1**	**V2**	**V3**
M1(8.00)	691.14	700.35	744.68	1097.57	1080.07	1079.92	37.03	35.16	31.04
M2(10.00)	688.90	694.17	732.17	1114.08	1090.16	1090.72	38.16	36.34	32.87
M3(12.00)	676.53	686.72	721.19	1121.15	1113.78	1098.24	39.66	38.34	34.33
M4(14.00)	664.03	675.29	690.67	1128.56	1126.65	1104.34	41.16	40.06	37.46
Mean	680.15	689.13	722.18**	1115.34**	1102.66	1093.31	39.00**	37.47	33.93
CD	2.57			2.94			0.38		

It was observed that there is significant difference at 1% level in between the varieties on true density. It was found highest (1115.34 kg/m^3) for Neelam variety and lowest in case of Sheela variety. It was also observed that moisture content also plays a vital role on true density. It was observed 1119.85 kg/m^3 in case of moisture content of 14% which was significantly highest (α=0.01). The increased value of true density with increase in moisture content were in agreement with the findings of Coskuner and Karbaba (2007); Selvi *et al.,* (2006).

It was observed that there is significant difference at 1% level in between the varieties on porosity. It was found highest (39.00) for Neelam variety and lowest in case of Sheela variety. It was also observed that moisture content also plays a vital role on true density. It was observed 39.56 in case of moisture content of 14% which was significantly highest (α=0.01). The observation of an increased in porosity of linseed with regards to increase in moisture content agree with the findings reported by, Selvi *et al.,* (2006) Bhishe *et al.,* (2013); Wang *et al*., (2007).

E. Effect of varieties and moisture content on Angle of repose for linseed

It was observed that there is significant difference at 1% level in between the varieties on angle of repose. It was found highest (22.05°) for Sheela variety and lowest in case of Shekhar variety. It was also observed that moisture content also plays a vital role on angle of repose. It was observed 22.70° in case of moisture content of 14% which was significantly highest (α=0.01). The observation of an increased in bulk density of linseed with regards to increase in moisture content agree with the findings reported by Selvi *et al.* (2006); Bhishe *et al.*, 2013.

It was observed that there is significant difference at 1% level in between the varieties on terminal velocity. It was found highest (2.77 m/s) for Neelam variety and lowest in case of Sheela variety. It was also observed that moisture content also plays a vital role on terminal velocity. It was observed 2.98 m/s in case of moisture content of 14% which was significantly highest (α=0.01). Similar result were found by many researchers Arafa *et al*., (2009) Sharma and Prasad (2013).

Table 5 : Effect of varieties and moisture content on angle of repose for linseed.

Moisture content (%)	Angle of repose (degree)			Terminal velocity(m/s)		
	V1	**V2**	**V3**	**V1**	**V2**	**V3**
M1(8.00)	20.52	20.27	20.92	2.44	2.43	2.24
M2(10.00)	21.31	20.73	21.72	2.60	2.50	2.38
M3(12.00)	22.16	21.33	22.45	2.91	2.61	2.57
M4(14.00)	23.19	21.81	23.11	3.14	3.01	2.78
Mean	21.80	21.04	22.05**	2.77**	2.64	2.49
CD	0.16			0.07		

F. Effect of varieties and moisture content on coefficient of friction for linseed

The coefficient of friction was measured on three surfaces namely GI sheet, MS sheet and plywood.

It was observed that there is significant difference at 1% level in between the varieties on coefficient of friction (GI-sheet, MS-sheet and plywood). It was found highest coefficient of friction 0.41, 0.48, 0.52for Sheela variety and lowest in case of Neelam variety in GI sheet, MS sheet and plywood surface respectively. The coefficient of friction for plywood surface was highest as compare to other surfaces. These observations are in agreement with other researchers Singh *et al*., (2013); Bhise *et al.*, (2013); Selvi *et al.*, (2006). It was also observed that moisture content also plays a vital role on coefficient of friction. It was observed 0.43, 0.49 and 0.53 in GI sheet, MS sheet and plywood surface respectively in case of moisture content of 14% which were significantly highest (α=0.01).

Table 6: Effect of varieties and moisture content on coefficient of friction for linseed.

Moisture content (%)	Coefficient of friction – GI sheet			Coefficient of friction – MS sheet			Coefficient of friction – Plywood		
	V1	V2	V3	V1	V2	V3	V1	V2	V3
M1(8.00)	0.34	0.35	0.35	0.39	0.39	0.42	0.44	0.39	0.47
M2(10.00)	0.36	0.37	0.39	0.42	0.42	0.46	0.47	0.42	0.50
M3(12.00)	0.38	0.40	0.43	0.45	0.45	0.50	0.50	0.46	0.54
M4(14.00)	0.41	0.42	0.48	0.47	0.48	0.53	0.53	0.50	0.56
Mean	0.37	0.38	0.41**	0.43	0.43	0.48**	0.49	0.44	0.52**
CD	0.01			0.01			0.01		

G. Rupture force

A time-domain image obtained by the semi-automatic texture analyzer and its supporting software. The impact force of the experimental linseed seed, linseed capsule and linseed pedicle for a single impact can be calculated indirectly. It can be seen from the Figure that the linseed seed absorbs the most energy. The equivalent stress-strain curves of such materials under impact loading is shown in The mean maximum force required to deform the seed, capsule and linseed pedicle were 4625g (46N), 599.85g and 808.13g respectively at moisture content of 16 % (d.b.). So that we required force for threshing linseed more than 599.85 g and less than 4625 g. Similar type of observation reported by Singh *et al*., (2012); Bhatt and Prasad (2018).

Table 7: Rupture force of linseed seed, linseed capsule and linseed pedicle at 16% moisture content.

Sample	Linseed seed	Linseed capsule	Linseed stalk tip
	Force (g)	**Force (g)**	**Force (g)**
1	5448.44	454.19	744.71
2	4674.05	829.43	756.71
3	4237.08	554.88	686.57
4	4613.68	578.54	1029.11
5	4153.57	582.21	823.56
Mean	4625.37	599.85	808.13
S.D.	513.15	138.48	132.77
C.V.	0.11	0.23	0.16

CONCLUSIONS

1. The mean value of physical property of linseed capsule, no. of capsule per plant, no of seed per capsule, length, width and thickness of capsule and geometric mean diameter (GMD) were 37.50, 9.59, 7.79mm, 6.57mm, 6.49 mm and 6.91mm respectively.

2. It was concluded that the mean value of linear dimensions i.e. length, width, thickness and geometric mean diameter (GMD) of linseed seed increased with increase in moisture content for all three varieties. However, the highest length, width and thickness was observed for the Neelam Variety of linseed as 5.53mm, 2.92mm 0.90 mm and 2.56 mm respectively at moisture content of 14 %.

3. The mean value of surface area, volume, 1000 grain weight of linseed increased with increase in moisture content for all three varieties. However, the highest surface area, sphericity, volume and 1000 grain weight were observed for the Neelam Variety of linseed as 21.51mm^2, 8.86mm^3 10.59 g respectively at moisture content of 14 %.

4. The mean value of true density, porosity of linseed increased with increase in moisture content for all three varieties. Whereas bulk density of linseed decreases with increase in moisture content However, the highest true density, porosity and lowest value of bulk density were observed for the Neelam Variety of linseed as 1128.56 kg/m^3, 41.16 and 664.03kg/m^3 respectively at moisture content of 14 %.

5. The mean value of angle of repose, coefficient of friction at GI sheet, MS sheet and plywood surface, terminal velocity of linseed increased with increase in moisture content for all three varieties. However, the highest angle of repose, coefficient of friction at GI sheet, MS sheet and plywood surface, terminal velocity were observed 23.19°, 0.41, 0.47, 0.53, and 3.14 at 14% moisture content.

6. The mean value of rupture force for linseed seed, linseed capsule, linseed stalk tip was observed 46.25 N, 5.99 N and 8.08 N respectively.

Conflict of Interest. The authors have not affirmed any conflict of interest.

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