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Studies on Some Engineering Properties of Faba Bean Seeds

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ABSTRACT

Various physical and mechanical properties of three different germplasm of faba bean seeds were evaluated.The average seed length of germplasm IC-0595985, IC-0595986 and IC-0595991were 8.71±0.66, 8.47±0.50 and 7.93±0.65mm, respectively. The three Indian germplasm of faba bean were found much lesser in dimension compared to the Egyptian varieties of faba bean. The geometric mean diameter, sphericity, thousand seeds mass and porosity were also determined.The averages of bulk density were 0.923±0.008, 0.918±0.014 and 0.88±0.002 g/cc, for germplasm IC-0595985, IC-0595986 and IC-0595991respectively .The coefficient of friction of seeds on two surfaces viz plywood and galvanized iron sheet were determined and it was observed that it was highest (0.42 ± 0.022) for plywood and lowest (0.38 ± 0.011) for GI sheet.

Keywords: faba bean,dimension, bulk density, coefficient of friction and angle of repose

INTRODUCTION

Pulses are the main source of proteins for vegetarians.Globally, faba bean (*Vicia faba* L.), is third most important feed grain legume after soybean (*Glycine max* L.), and pea (*Pisum sativum* L.) with a total production of 4.87 MT and harvested area of 2.63 Mha, as reported by Mihailovic *et al.* (2005). In India, about 15-30 per cent of the daily protein needs are supplied from edible legumes or pulses. Razia Akbar (2000) reported the practice of cultivation and soil enhancing properties of faba bean in India. Being one of the most potential crops to serve humanity at global level, unfortunately in India it is still treated as a minor legume / unutilized / underutilizedcrop (Singh *et al.,*2009; Singh *et al*., 2012). China is currently the world leading producer with 60% of the total yield followed by Northern Europe, Mediterranean, Ethiopia, Central and East Asia and Latin America (FAOSTAT, 2009).

It is cultivated during winter (states of seasons) in plains and during rainy season (*Kharif*) in hilly and mountainous region. It is as an agronomically viable alternative to cereal grains (Singh *et al*., 2013). It is being taken as sole crop and as intercropped/mixed crops with variety of combination even as border / guard crop in eastern India (Singh *et al*., 2009 and Singh *et al.,*2012).Each year, seed developers release many varieties into the market that provide improved productivity and adaptability to adverse conditions. These varieties are nearly similar in their characteristics and different in their properties. Knowledge of faba bean physical and mechanical properties are very important in the design equipment for handling, drying, aeration, storing structures and processing.

Faba bean size and shape varies with, variety and seed moisture content. Fraser *et al.* (1978) reported that for faba bean, the thousand seed mass, angle of repose and static coefficient of friction increased with an increase in moisture content while bulk density decreased. Abu El-Kheir (1988) indicated that faba bean seed characteristic dimensions and varieties might have an effect on threshing and cleaning efficiencies. The seed form and dimensions are considered important as limiting factors in passing the grain between the concave holes for separating and cleaning machine. He also reported that there is a significant difference in seed dimensions with varieties of faba bean. There

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are also very good reasons why the frictional properties of seeds should be known. To name some examples: estimation of power requirements for the transportation of the product; calculating the lateral pressure in a silo wall. Such data will not only affect the shapes and dimensions of storage, flow characteristics in the handling, and methods of processing units, but also overall costs.

The objective of this study was to investigate physical, namely, axial dimensions, thousand seed weight, geometric mean diameter, Sphericity,bulk density, true density, porosity, and mechanical properties namely angle of repose and coefficient of friction of three different faba bean seed varieties.

MATERIALS AND METHODS

Sample Preparation

Faba bean was cultivated in the field of ICAR Research Complex for Eastern Region,Patna, Bihar. The seeds obtained from crop were cleaned manually with freshwater to remove all foreign materials and approximately 1 kg of seeds of each varieties were taken for the study.

Measurement of Moisture

The moisture content of faba bean seeds was determined using American Society of Agricultural Engineers (ASAE) standard method (ASAE, 4). Predetermined quantity of seed samples were dried in a hot air oven and weight at regular interval after cooling the samples. The process is continued till constant weight was obtained. The moisture content on Wet basis of faba bean seeds was calculated using equation (1)

Moisture content (%)

$$= \frac{\text{(Initial weight of seeds - Final weight of seeds)}}{\text{Initial weight of seeds}} \qquad \text{(Eq.1)}$$

Axial Dimensions

The axial dimensions includes length, breadth and thickness of the seeds. Fifty seeds of each variety were randomly selected from the lots to determine the average size of the faba bean seed. Measurements of the three major perpendicular dimensions of the seed were carried out with a digital caliper to an accuracy of 0.01 mm. The geometric mean diameter, D_g of theseed was calculated by using the equation (2) (Mohsenin, 1986):

$$Dg = (LWT)^{1/3} \qquad \text{(Eq.2)}$$

Where,D_g = Geometric Mean Diameter, mm; L=Length, mm; W=Width,mm and T= Thickness,mm.

Sphericity

The sphericity (ϕ), of faba bean seeds is calculated using the following equation (3) (Mohsenin, 1970):

$$\phi = \frac{[LWT]^{1/3}}{L} \qquad \text{(Eq. 3)}$$

Thousand Seed Weight

The weight of 1000 seed was obtained by counting 1000 seeds at the desired moisture content and weighed on an electronic balance.Average of five replications along with standard deviation is presented.

Bulk Density

Bulk density and porosity affect the structural loads. The bulk density is the ratio of the mass sample of the seeds to its total volume. It was determined by filling a 1000 cc container with seeds from a height of about 15 cm, and then weighing the contents. The bulk density was calculated using the equation (4).

$$\phi = \frac{[LWT]^{1/3}}{L}$$

$$\rho_b = \frac{w}{v} \qquad \text{(Eq. 4)}$$

Where, ρ_b=Bulk density, gm/cm^3; W =Weight of seed sample, gm and V = volume of seed sample, cm^3

True Density

The true density was determined using toluene displacement method in order to avoid absorption of water during experiment (Jha, 1999; Singh & Goswami, 1996). It is the ratio of the mass of faba bean seeds to their true volume of the seeds. The seeds were used to displace toluene in a measuring cylinder after their masses had been measured. The true density was found as an average of the ratio of their masses to the volume of toluene displaced by the seeds.

Porosity

The porosity was determined by the following equation:

$$\varepsilon = \left[1 - \frac{\rho_b}{\rho_t}\right] \times 100 \qquad \text{(Eq. 5)}$$

Where and are the bulk and true densities respectively (Mohsenin, 1970).

Coefficient of Friction

The coefficient of friction between seed and wall is an important parameter in the prediction of seed pressure on walls. The coefficient of friction of the faba bean seeds on three different surfaces such as GI sheet, plywood and Plastic laminates were determined. These are common materials used for transportation, storage and handling operations of grains, pulses and seeds, construction of storage and drying bins. A tilting platform of 400 mm×200mm was fabricated and used for fabrication in experimentation. An-open ended PVC pipe having 63 mm diameter and 40 mm height was filled with the seed and placed on the adjustable titling surface. The cylinder was raised slightly so as not to touch the surface. The structural surface with the cylinder resting on it was inclined gradually with a screw jack, until the material started to flow (Lorenzen, 1959) and the angle of tilt was read from a graduated scale (Fraser *et al.,*1978; Dutta *et al.,*6; Nimkar *et al.,*2005). The coefficient of friction was calculated using the equation (6).

$$\mu_s = \tan\alpha \qquad \text{(Eq. 6)}$$

Where, is coefficient of friction; and is angle of inclination of material surface.

Angle of Repose

The angle of repose indicates the cohesion properties of the seed. The angle of repose of faba bean seeds was measured by the emptying method (Bart-Plange and Baryeh, 2003). The angle of repose was determined by using an open ended rigid PVC pipe having 63 mm diameter and 500 mm height. The cylinder was placed at the centre of circular plate having a diameter 700 mm and was filled with faba bean seeds. The cylinder was raised slowly until it formed a cone. The height of the cone was recorded by using a movable pointer fixed on a stand having a scale of 0.1 mm precision. The angle of repose (θ) was calculated using equation (7).

$$\theta = \tan^{-1}\frac{2H}{D} \qquad \text{(Eq. 7)}$$

Where, θ is angle of repose in degree, H is the height of the cone in mm and D is the diameter of cone in mm.

RESULTS AND DISCUSSION

Axial dimensions are important in determining aperture sizes and other parameters in machine design (Mohsenin,1986). The average seed moisture at the time of experiment was 10.10±0.33% on dry basis. The average seed length of germplasm IC-0595985, IC-0595986 and IC-0595991were 8.71±0.66, 8.47±0.50 and 7.93±0.65mm, respectively; however the width of the respective germplasm were 6.72±0.39, 6.30±0.36 and 6.26±0.32mm (Table 1). These three Indian germplasms of faba bean were found much lesser in dimension compared to the Egyptian varieties of faba bean as reported by Shoughy and Amer(2006).The sphericity which is a measure of roundness of the object, of germplasm IC-0595985, IC-0595986 and IC-0595991 were found to be 81.35±3.38, 78.55±2.55 and 83.03±4.42. Shoughy and Amer, (2006) reported a lesser range of spherecity i.e. 65-70 for Egyptian faba bean. This means that the Indian varieties of faba bean are much rounder than the Egyptian counterparts.

The averages of bulk density were 0.923±0.008, 0.918±0.014 and 0.88±0.002 g/cm^3, for germplasm IC-0595985, IC-0595986 and IC-0595991 respectively (Table 1). The bulk densities of germplasm IC-0595991 were found 4.66 and 4.14

Table 1: Descriptive statistics for Faba bean seeds at moisture contents of 10.10% (db)

Particulars	Germplasms		
	IC-0595985	IC-0595986	IC-0595991
Length (L),mm	8.71±0.66	8.47±0.50	7.93±0.65
Width (W),mm	6.72±0.39	6.30±0.36	6.26±0.32
Thickness (T), mm	6.05±0.42	5.51±0.33	5.71±0.33
Geometric Mean Diameter (GMD),mm	7.07±0.43	6.64±0.33	6.57±0.33
Sphericity	81.35±3.38	78.55±2.55	83.03±4.42
Thousand seed weight, g	287.0±5.01	281.80±7.26	239.40±11.74
Bulk density, g/cm^3	0.923±0.008	0.918±0.014	0.88±0.002
True density, g/cm^3	1.338±0.035	1.336±0.011	1.287±0.017
Porosity, %	31.034±1.38	31.264±1.43	31.49±1.05
Angle of repose, degree	22.25±1.66	22.86±1.31	21.29±0.74

per cent less than IC-0595985 and IC-0595986 respectively. The porosity of the seeds of faba bean of germplasm IC-0595985, IC-0595986 and IC-0595991 were 31.034±1.38 %, 31.264±1.43 % and 31.49±1.05 % respectively.

these properties should be evaluated at different moisture content conditionsso as to establish relationship between moisture content and various engineering properties of faba bean seeds.

Table 2: Frictional properties of faba bean seeds at moisture contents of 10.10% (db)

Coefficient of friction	GI sheet			Plywood		
	IC-0595985	IC-0595986	IC-0595991	IC-0595985	IC-0595986	IC-0595991
N	5	5	5	5	5	5
Mean	0.39	0.39	0.38	0.43	0.42	0.41
SD	0.013	0.014	0.011	0.022	0.019	0.011

NB: N is the number of samples

The average value of angle of repose of the faba bean seed was found between 21.29° to 22.86°. It was observed that the mean angle of repose is considerably lower than that reported for sesame seed as 32° by Tunde-Akintunde and Akintunde, (2004), and mean angle of repose of pumpkin and watermelon (Altuntas, 2008). The smoother outer surface and the shape of the seeds are apparently responsible for the lower values of repose angle, and thus the easiness of the seeds to slide on each other.

The results of the coefficient of friction, which may directly and indirectly affecting the design of the processing machine, was determined on two different material surfaces (galvanized iron sheet and plywood), have been tabulated in table 2. It was observed that the coefficient of friction was highest (0.42 ± 0.022) for plywood and lowest (0.38 ± 0.011) for GI sheet. The least coefficient of friction may be owing to the smoother and more polished surface of the GI sheet than the other materials used. This data on the coefficient of friction will be important for designing any pneumatic conveying system, screw conveyors, forage harvesters and threshers, etc.

CONCLUSION

The mean length, geometric mean diameter, spherecity, bulk density, true density, porosity, angle of repose, coefficient of friction of germplasm IC-0595985of faba bean seeds at 10.10 % moisture content were 8.71± 0.66mm, 7.07±0.43mm, 81.35±3.38,0.923±0.008g/cm^3,1.338±0.035 g/ cm^3, 31.034±1.38%, 22.25°±1.66 and 0.39±0.013 respectively. The other two germplasm also showed almost similar properties. There is not much significant difference in the engineering properties amongst the three germplasm. However

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