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Engineering Properties of Field Beans (*Lablab purpureas L.*) at Different Soaking Time

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A B S T R A C T

Field bean (*Lablab purpureas L.)* is one of the most important leguminous vegetables grown for its tender fleshy green pods, shelled green seeds and also dry beans. Prior to consumption, field beans are subjected to soaking which causes important changes in their physical, frictional and aerodynamic properties. Several engineering properties of fresh field beans and soaked beans (for 4 h, 8 h and 12 h soaking time) were evaluated. Standard methods were followed to investigate changes in properties of fresh and soaked field beans. The moisture content, axial dimensions, shape, geometric and arithmetic mean diameter, sphericity, surface area, aspect ratio, unit volume, thousand beans weight, true density, bulk density, porosity ranged from 64.22 to 71.88% (w.b.), 11.43 to 12.14 mm for length, 8.71 to 9.25 mm for width and 5.53 to 5.83 mm for thickness, oblong, 8.19 to 8.68 mm, 8.56 to 9.04 mm, 0.724 to 0.714, 211.24 to 237.14 mm^2, 0.762 to 0.761, 91.93 to 107.74 mm^3, 326 to 374 g, 1240 to 1299 kg. m^{-3}, 636.74 to 597.15 kg. m^{-3} and 41.13 to 48.50%, respectively. The frictional properties such as angle of repose, coefficient of internal and external friction ranged from 33.28 to 37.74°, 0.71 to 0.75 and 0.64 to 0.69 respectively and terminal velocity ranged from 11.20 to 12.33 m. s^{-1} for whole beans, 7.50 to 9.33 m. s^{-1} for dehulled beans and 4.0 to 5.40 m. s^{-1} for husk.

Introduction

Pulses are rich in proteins and are the main source of protein to vegetarians of India. Pulses are the second important constituent of Indian diet after cereals. Peas, beans, lentils and all other pulses belong to a group scientifically known as *leguminosae.* Field bean (*Lablab purpureus L.*) is one of the most important leguminous vegetables grown for its tender fleshy green pods, shelled green seeds and also dry beans. In India, the major field bean growing states are Karnataka, Tamil Nadu and Andhra Pradesh. In Karnataka, it occupies an area of 0.83 lakh hectares with a production of 0.67 lakh tonnes and productivity of 858 kg. ha^{-1} (www. raitamitra.kar.nic.in, 2013).

Many food properties show a unique dependence on the state of the water in a food material. Soaking has been shown to cause a change in the engineering properties of food material. Recently scientists have made great efforts in evaluating basic physical properties of agricultural materials and have pointed out their practical utility in machine and structural design and in control engineering (Amin *et al*., 2004).

Recent scientific developments have improved the handling and processing of bio-materials through thermal, electrical, optical and other techniques, but little is known about the basic physical characteristics of biomaterials. Such basic information is important not only to engineers but also to food scientists, processors, plant breeders and other scientists who may find new uses (Mohsenin, 1978). Dimensions are important in the design of cleaning, sizing and grading machines. Bulk density and porosity are major considerations in designing drying and aeration and storage systems, as these properties affect the resistance to air flow of the mass (Amin *et al.*, 2004; Dursun and Dursun, 2005). Awareness of the coefficient of friction is crucial in designing equipment for solid flow and storage structures. The coefficient of friction between grains and wall is an important parameter in the prediction of grain pressure on walls.

The engineering properties of field beans are important for the processing of field beans into commercial food products and to design post harvest handling and processing machines for field beans. Therefore, the objective of this study was to determine the engineering properties of field beans at different soaking time.

Materials and Methods

Raw material

The field bean pods were procured from local market of Malur (Kolar), Karnataka. The field beans were peeled manually for separation of beans from the pods. The methods followed for the determination of engineering properties of fresh field beans and soaked field beans (4 h, 8 h and 12 h) is discussed below. The field beans are shown in plate 1.

Moisture content

The moisture content (%) of whole field beans was determined using the procedure detailed by Henderson *et al*. (1997). Ten grams of field beans were oven dried at 105°C for 24 hours (ASAE, 2003). The weight loss of sample was recorded and the moisture content was determined in percentage. The average moisture content was calculated using the following relationship (Simonyan *et al.*, 2009).

$$\text{Moisture content (\% w.b.)} = \frac{W_1 - W_2}{W_1} \times 100$$

where,

W_1 = Initial weight of sample, g
W_2 = Final weight of sample, g

Shape and size

The shape of the field bean was determined by measuring the longitudinal and lateral diameters using the digital screw gauge having a least count of 0.01 mm. The dimensions were compared with the shapes as described in the standard chart (Mohsenin, 1986). The average size of the field bean was calculated from randomly selected 100 field beans in terms of linear dimensions such as length, width and thickness.

Geometric and arithmetic mean diameter

The geometric and arithmetic mean diameter (D_g) of the field bean was calculated by using the following relationship (Kenghe *et al*., 2013; Ghamari *et al*., 2014).

$$D_g = (LWT)^{\frac{1}{3}}$$

$$D_a = \frac{(L + W + T)}{3}$$

where,

D_g = Geometric mean diameter, mm
D_a = Arithmetic mean diameter, mm
L = Length, mm
W = Width, mm
T = Thickness, mm

Sphericity

Sphericity shows the shape character of the object relative to the sphere having the same volume. The sphericity of field bean was calculated by using the following formula (Sahay and Singh, 2012).

$$\text{Sphericity} = \frac{(L \times W \times T)^{\frac{1}{3}}}{L}$$

Surface area

The surface area of field bean was determined by analogy with a sphere of same geometric mean diameter, using the following relationship (Tavakoli *et al*., 2009).

$$S = \pi(D_g)^2$$

Unit volume and aspect ratio

The unit volume and aspect ratio of field beans were calculated by using the following equations (Wani *et al*., 2017).

$$\text{Aspect ratio } (R_a) = \frac{W}{L}$$

$$\text{Unit volume } (V) = \frac{L \times W \times T}{6}$$

True density

The apparatus used for measuring the true density of beans consists of a 100 ml measuring jar and a weighing balance (Essae, e = 2g). Fifty ml of toluene was taken in a measuring jar. A known weight (10 g) of field beans were poured into the measuring jar and rise in the toluene level was recorded as the true volume of the beans without void space. The true density of field beans was calculated by using the following formula (Mohsenin, 1986).

$$\text{True density } (kg.\ m^{-3}) = \frac{\text{Weight of beans (kg)}}{\text{change in volume of toluene } (m^3)}$$

Bulk density

The bulk density of the agricultural products plays an important role in many applications, sizing grain hoppers and storage facilities (Heridarbeigi *et al*., 2009). The bulk density of field beans was determined by using a container of known volume. The container was weighed in an electronic balance (Essae, e = 2g) filled with the beans. The bulk density was calculated by using the following formula (Mohsenin, 1986).

$$\text{Bulk density } (kg.\ m^{-3}) = \frac{\text{Weight of material (kg)}}{\text{Volume of material including pore space } (m^3)}$$

Porosity

The porosity is the percentage of volume of voids in the test sample at a given moisture content. It was calculated as the ratio of the difference in true density and bulk density to the true density value and expressed in percentage and was calculated by using the following equation for field beans (Kenghe *et al*., 2013).

$$\text{Porosity} \quad (\varepsilon) = \frac{\rho_t - \rho_b}{\rho_t} \times 100$$

Thousand beans weight

Weight of 1000 whole field beans was determined by taking 100 beans randomly and measuring the weight of beans at different soaking times by using an electrical balance and then multiplying by 10 to give the weight of 1000 field beans (Amin *et al.,* 2004).

Angle of repose

The angle of repose is the angle between base and slope of the cone formed on a free vertical fall of field beans on to a horizontal plane. It was determined by following the procedure described by Sahay and Singh (2012). From the height and diameter of field beans heaped in natural piles, the angle of repose was calculated by using the following formula

$$\text{Angle of repose} \quad (\varphi) = \tan^{-1}\left[\frac{2H}{D}\right]$$

where,

φ = Angle of repose, degrees
H = Height of heap, mm
D = Diameter of heap, mm

Coefficient of internal friction

Coefficient of internal friction is the friction between the grain mass of kernels against each other. The coefficient of internal friction was measured by using a table provided with changeable surfaces. A box of size 7.5 cm×7.5 cm×9.5 cm was tied by cord passing over pulley is attached to cord. The changeable surface was filled with field beans. The weights (W_1) were put into pan until the empty box started to slide on beans surface. Later, the empty box filled with known weight of sample (W) and again the weights were put into pan to cause sliding. The weights (W_2) required to slide the filled box on the beans surface was recorded (Amin *et al.*, 2004).

$$\text{Coefficient of internal friction} \quad (\mu_i) = \frac{W_2 - W_1}{W}$$

Coefficient of external friction

Coefficient of external friction is the sliding stress between the grain and the horizontal plane against the wall. The coefficient of external friction was measured by using a table provided with changeable surfaces. The box of the size 7.5 cm×7.5 cm×9.5 cm was tied by cord passing over pulley and pan was attached to cord. The weights (W_1) were put into pan until the empty box started to slide. Later, the box was filled with known weight of sample (W) and again the weights were put into pan to cause sliding. The weights (W_2) required to slide the filled box was recorded (Amin *et al.*, 2004).

$$\text{Coefficient of external friction} \quad (\mu_e) = \frac{W_2 - W_1}{W}$$

Terminal velocity

The terminal velocity of field beans was measured using an air column in which the material was suspended in the air stream. Relative opening of a regulating valve provided at blower output end was used to control the airflow rate. In the beginning, the blower output was set at minimum. For each test, a sample was dropped in the air stream from the top of an air column. Then the airflow rate was gradually increased till the beans mass was suspended in the air stream. Air velocity near the location of beans suspension was measured using a digital anemometer having a least count of 0.1 m. s^{-1} (Nimkar and Chattopadhyay, 2001).

Results and Discussion

The engineering properties of fresh and soaked field beans for 4 h, 8 h and 12 h are presented in Table 1.

Physical properties

The moisture content of field beans increased with increase in soaking time from 4 h to 12 h as presented in Figure 1 and the values were found to be 64.22% for fresh beans and 69.13% for 4 h, 71.63% for 8 h and 71.88% for 12 h soaked beans. The increased moisture content could be due to the moisture absorbed by field beans. Similar results were reported by Myrene *et al.,* (2013).

The shape of fresh and soaked (4, 8 and 12 hours) beans was found to be oblong. The average values of linear dimensions *viz.,* length, width and thickness of field beans were found to be 11.43, 8.71, 5.53 mm for fresh beans, 11.75, 9.06, 5.79 mm for 4 h soaked beans, 12.08, 9.19, 5.81 mm for 8 h soaked beans and 12.14, 9.25, 5.83 mm for 12 h soaked beans, respectively and are presented in Figure 2. It could be due to the increase in moisture content of field beans as the soaking time increased. Similar increasing trend in linear dimensions was reported by Simonyan *et al.,* (2009) for *Lablab purpureus* (L.) sweet seeds.

The average values of geometric and arithmetic mean diameter of field beans were found to be 8.19 mm for fresh beans and 8.51 mm for 4 h, 8.64 mm for 8 h and 8.68 mm for 12 h soaked beans and 8.56 mm for fresh beans, 8.94 mm for 4 h soaked beans, 8.99 mm for 8 h soaked beans and 9.04 mm for 12 h soaked beans respectively and are shown in Figure 3. As the soaking time increased the geometric and arithmetic mean diameter are increased, due to increase in axial dimensions of field beans. The recorded values were similar to the findings of Simonyan *et al.* (2009) for *Lablab purpureus* (L.) sweet seeds.

The outlined average value of sphericity for fresh field beans was found to be 0.716 and for soaked beans the values were 0.724 for 4 h, 0.715 for 8 h and 0.714 for 12 h soaked beans and are shown in Figure 4. Simonyan *et al.* (2009) reported the sphericity of lablab seeds decreased as the moisture content increased for *Lablab purpureus* (L.) sweet seeds.

The average values of aspect ratio of field beans were found to be 0.762 for fresh beans and 0.771 for 4 h, 0.760 for 8 h and 0.761 for 12 h soaked beans and are presented in Figure 4. It indicates that there was an decrease in aspect ratio with an increase in soaking time. Similar trend has been reported by Oginni (2016) for *Moringa oleifera* kernals.

From Figure 5, the numerical mean values of surface area of field beans were found to be 211.24 mm^2 for fresh beans, 227.74 mm^2 for 4 h soaked beans, 234.75 mm^2 for 8 h soaked beans and 237.14 mm^2 for 12 h soaked beans. The higher surface area could be due to the change in major dimensions of the field beans. Similar increasing trend as been reported by Deshpande *et al.,* (1993) for soybean.

The relationship between soaking time and unit volume for field beans is shown in Figure 6. As the soaking time increased, the mean values of unit volume of field beans were found to be 91.93 mm^3 for fresh beans and 105.42 mm^3 for 4 h, 106.64 mm^3 for 8 h and 107.78 mm^3 for 12 h soaked beans were also increased. Volume is dependent on their linear dimensions, the change in linear dimensions reflected in the change in volume too. A similar increasing trend was observed by Altuntas and Demirtola (2007) for some legume seeds such as kidney beans, Pea and blue eyed pea.

The effect of soaking time on true density of field beans showed a linear increase with soaking time (Fig. 8). The experimental results in respect of true density of field beans were found to be 1015.75 kg. m^{-3} for fresh beans and 1097.14 kg. m^{-3} for 4 h, 1134.20 kg. m^{-3} for 8 h and 1143.65 kg. m^{-3} for 12 h soaked beans. The increase in true density with soaking time was due to relatively higher true volume as attributed due to water absorption. The results were similar to Kiani *et al.* (2008) for red bean.

A plot of experimentally obtained values of bulk density against soaking time is shown in Figure 8. The results indicated a decrease in bulk density with an increase in soaking time and were found to be 636.74 kg. m^{-3} for fresh beans and 616.92 kg. m^{-3} for 4 h, 600.45 kg. m^{-3} for 8 h and 597.15 kg. m^{-3} for 12 h soaked beans. This decrease in bulk density was due to the fact that, the increase in mass due to increase in moisture was lower than that of volumetric expansion of bulk grains. The values for bulk density reported by Deshpande *et al.* (1993) showed similar decreasing trend was observed for soybean.

The porosity of field beans was found to increase linearly with increase in soaking time from 0 to 12 h as shown in Figure 9. The average values were found to be 37.01% for fresh beans and 43.62% for 4 h, 47.02% for 8 h and 47.02% for 12 h soaked beans. The porosity depends on the bulk as well as true densities, the magnitude of variation in porosity depends on these factors only. Kiani *et al.*, (2008) reported a similar increasing trend in porosity for Goli and Akhtar of red bean varieties.

The weight of 1000 beans at different soaking times is presented in Figure 7. The numerical mean values of thousand beans weight of field beans were found to be 326.04 g for fresh beans and 357.36 g for 4 h, 366.98 g for 8 h and 374.10 g for 12 h soaked beans. Weight of 1000 beans was dependent on moisture content and increased as the soaking time increased. Amin *et al.* (2004) reported similar increasing trend as the moisture increased for kidney bean, pea and black eyed pea.

Frictional properties

The experimental results for the angle of repose with respect to soaking time are shown in Figure 10. The values were found to be 33.28° for fresh beans and 35.78° for 4 h, 36.23° for 8 h and 37.74° for 12 h soaked beans. The angle of repose increased with increase in soaking time (0 to 12 h). At higher moisture content, the grain might tend to stick together resulting in better stability and less flow ability, which increased the angle of repose. The similar increasing trend in angle of repose was reported by Amin *et al.* (2004) for lentil.

The coefficient of internal friction of field beans on metal surface with various soaking time (0 to 12 h) are presented in Figure 11. It is seen that the coefficient of internal friction increase with increase in soaking time for metal surface. This is due to the increased adhesion between the beans. The average values of coefficient of internal friction were found to be 0.71 for fresh beans and 0.72 for 4 h, 0.73 for 8 h and 0.75 for 12 h soaked beans on the metal sheet. The similar increasing trend was reported by Coskun *et al.* (2006) for sweet corn.

The average values of coefficient of external friction of field beans were found to be 0.64 for fresh beans, 0.65 for 4 h, 0.68 for 8 h and 0.69 for 12 h soaked beans. It was observed that the coefficient of external friction for field beans was increased with increased soaking time as shown in Figure 11. It could be due to the increased adhesion between beans and metal surface at higher moisture values**.** Nimkar and Chattopadhyya (2001) reported that the moisture increased the coefficient of external friction for green gram.

Table.1 Engineering properties of fresh and soaked field beans

Sl.No.	Parameters	Fresh beans	Soaked beans			S.Em	CD@1%	CV
			4 h	8 h	12 h			
1	Moisture(%) (w.b.)	64.22	69.13	71.63	71.88	0.77	3.65	1.92
Physical properties of field beans								
2	Length(mm)	11.43	11.75	12.08	12.14	0.13	0.36	5.5
3	Width (mm)	8.71	9.06	9.19	9.25	0.11	0.31	6.18
4	Thickness (mm)	5.53	5.79	5.81	5.83	0.1	0.21	8.66
5	Geometric mean diameter (mm)	8.19	8.51	8.64	8.68	0.07	0.11	4.44
6	Arithmetic mean diameter (mm)	8.56	8.94	8.99	9.04	0.07	0.11	4.59
7	Sphericity	0.716	0.724	0.715	0.714	0.007	0.01	5.1
8	Surface area (mm^2)	211.24	227.78	234.75	237.14	4.12	5.83	9.07
9	Aspect ratio	0.762	0.771	0.760	0.761	0.01	0.01	8.16
10	Unit volume (mm^3)	91.93	105.42	106.64	107.78	2.77	3.92	13.45
11	True density ($kg.\ m^{-3}$)	1015.75	1097.14	1134.2	1143.65	24.83	102.27	5.05
12	Bulk density ($kg.\ m^{-3}$)	636.74	616.92	600.45	597.15	5.94	24.56	2.17
13	Porosity (%)	37.01	43.62	47.02	47.76	1.39	5.77	7.12
14	Thousand beans weight (g)	326.04	357.36	366.98	374.1	5.22	21.48	3.26
Frictional properties of field beans								
15	Angle of repose (°)	33.28	35.78	36.23	37.74	0.63	2.61	3.96
16	Coefficient of internal friction	0.71	0.72	0.73	0.75	0.005	0.03	1.44
17	Coefficient of external friction	0.64	0.65	0.68	0.69	0.008	0.01	2.78
Terminal velocity								
18	Whole beans ($m.\ s^{-1}$)	11.2	11.8	12.13	12.33	0.24	1.16	3.56
19	Kernel ($m.\ s^{-1}$)	7.5	8.56	9.03	9.33	0.3	1.45	6.14
20	Husk ($m.\ s^{-1}$)	4	5.13	5.2	5.4	0.2	0.95	7.04

S.Em ± = Sum error mean
CV = Coefficient of variation
CD@ 1% = Critical difference

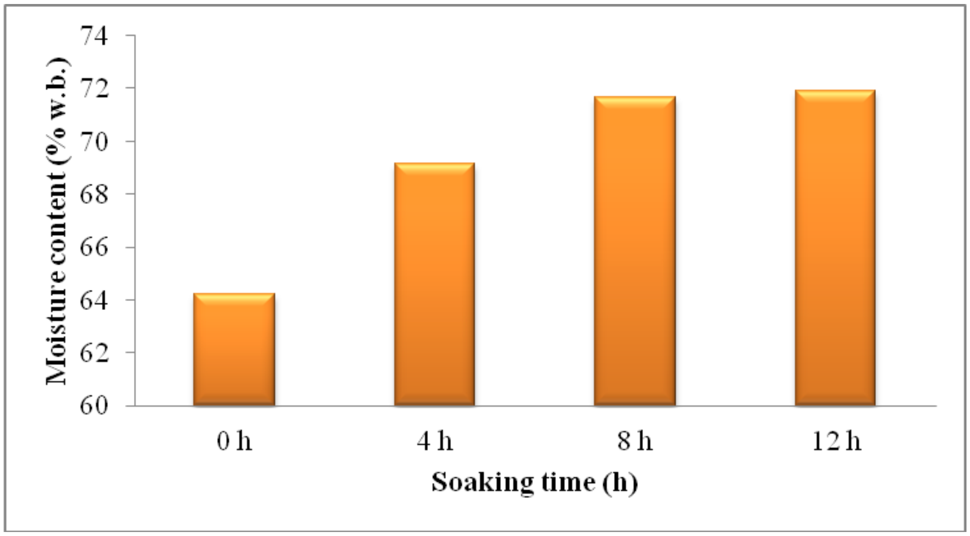

Fig.1 Effect of soaking time on moisture content of field beans

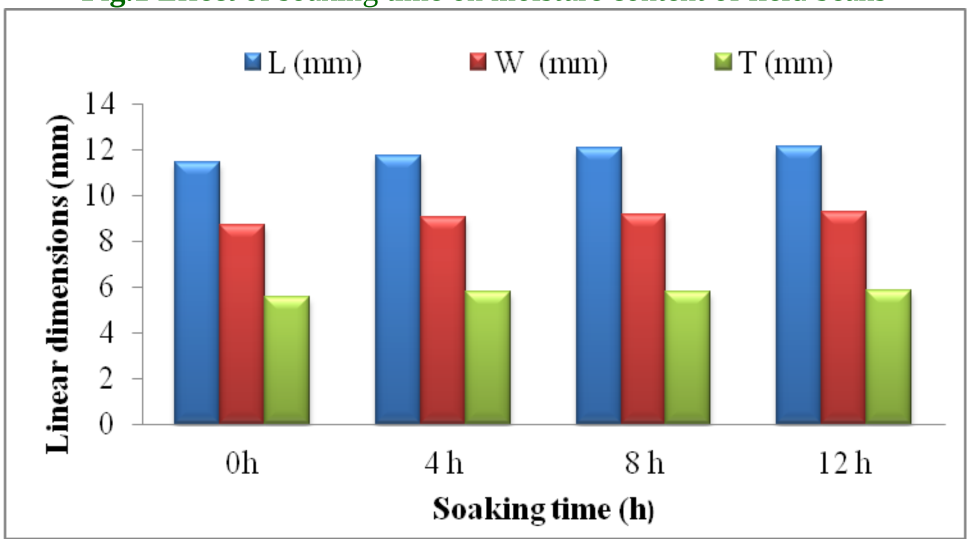

Fig.2 Effect of soaking time on linear dimensions of field beans

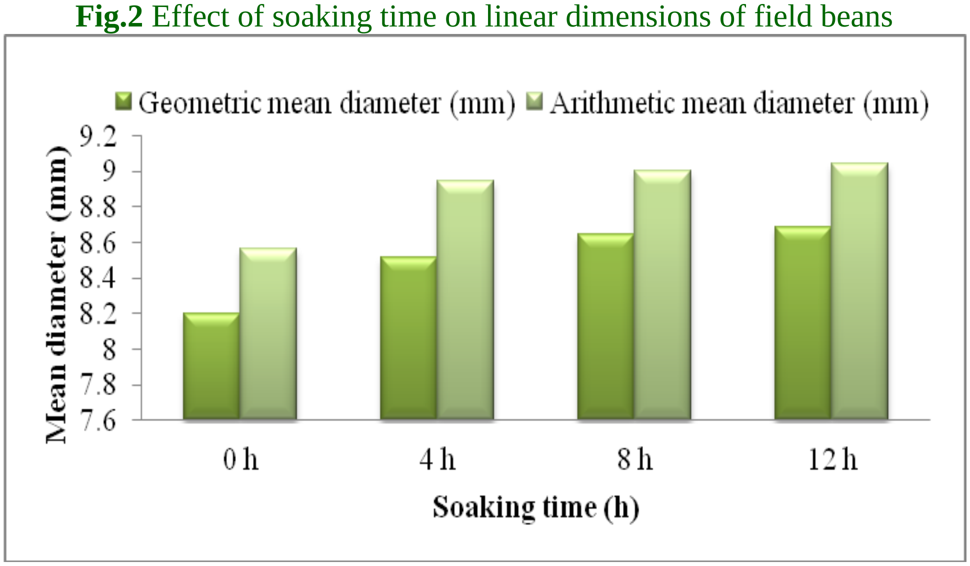

Fig.3 Effect of soaking time on mean diameter of field beans

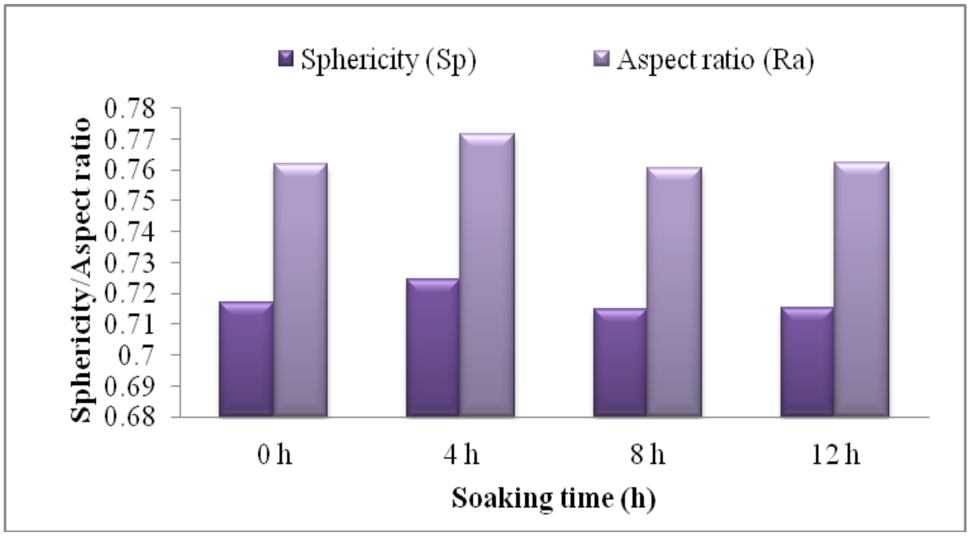

Fig.4 Effect of soaking time on sphericity and aspect ratio of field beans

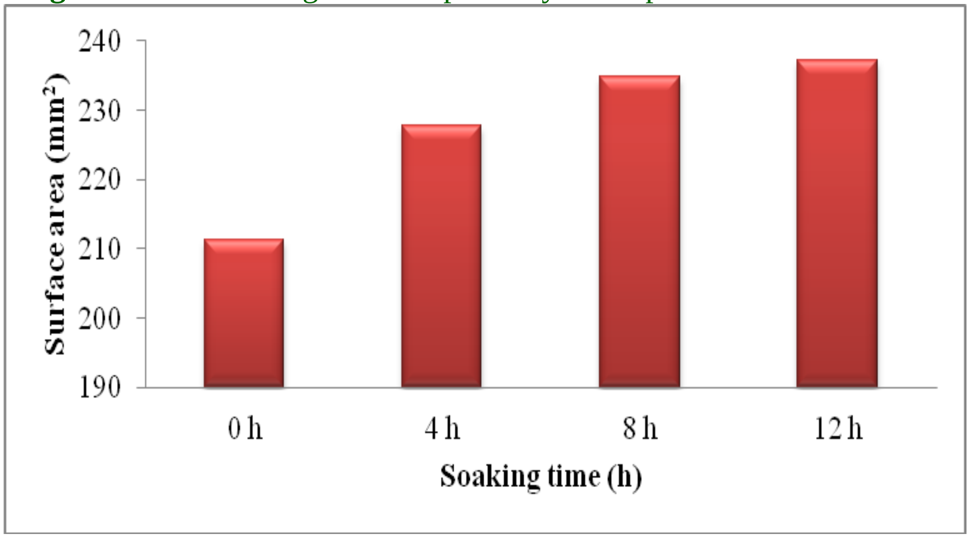

Fig.5 Effect of soaking time on surface area of field beans

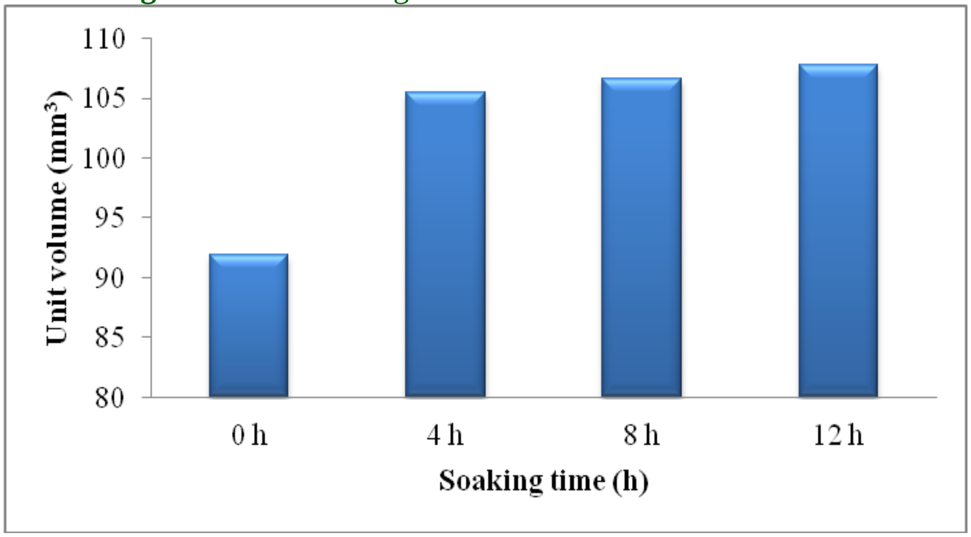

Fig.6 Effect of soaking time on unit volume of field beans

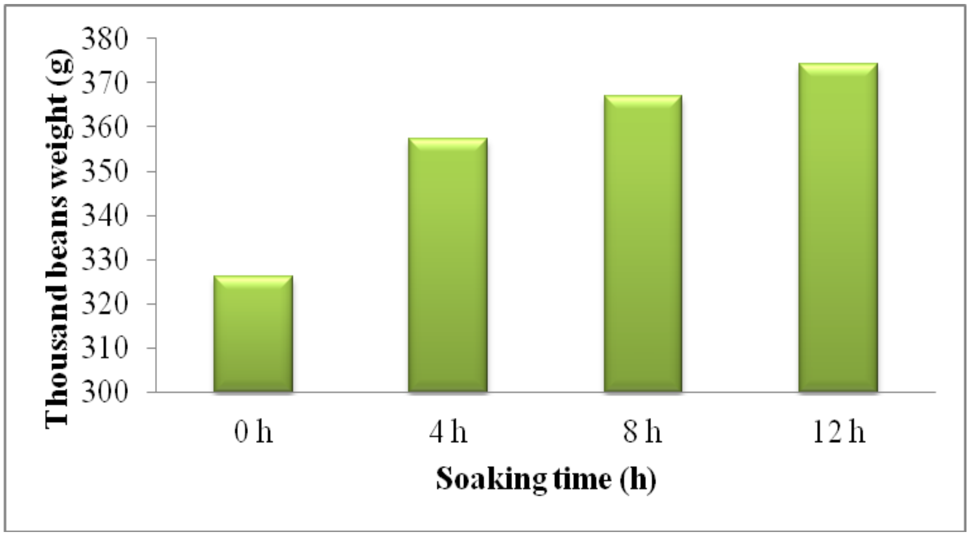

Fig.7 Effect of soaking time on thousand beans weight of field beans

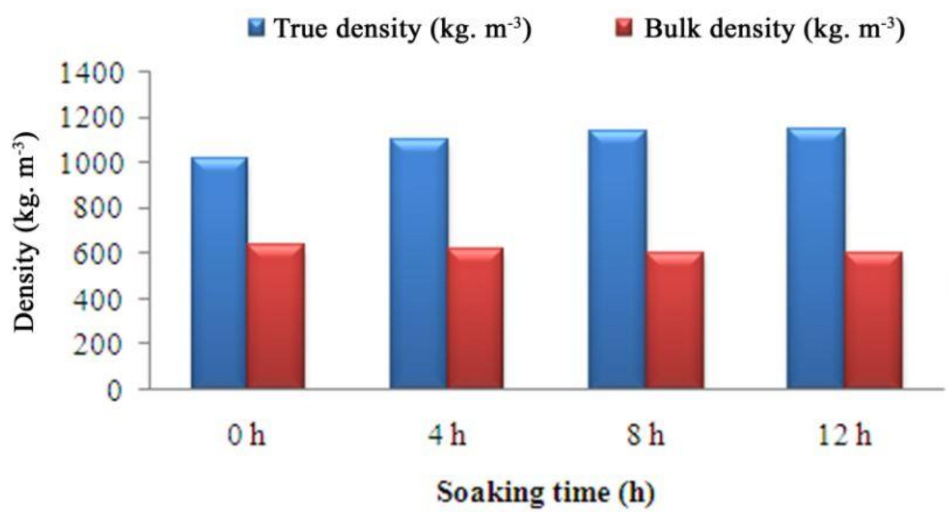

Fig.8 Effect of soaking time on density of field beans

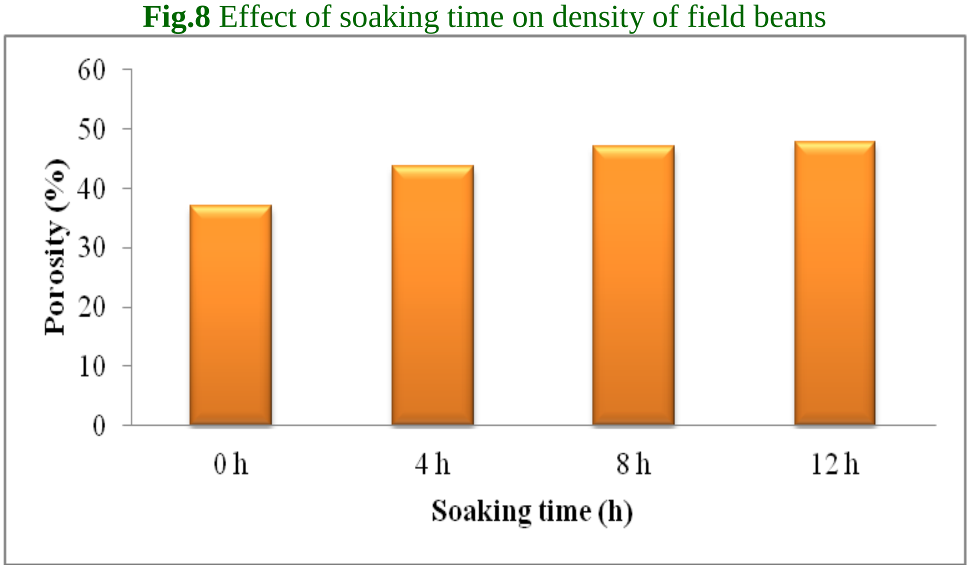

Fig.9 Effect of soaking time on porosity of field beans

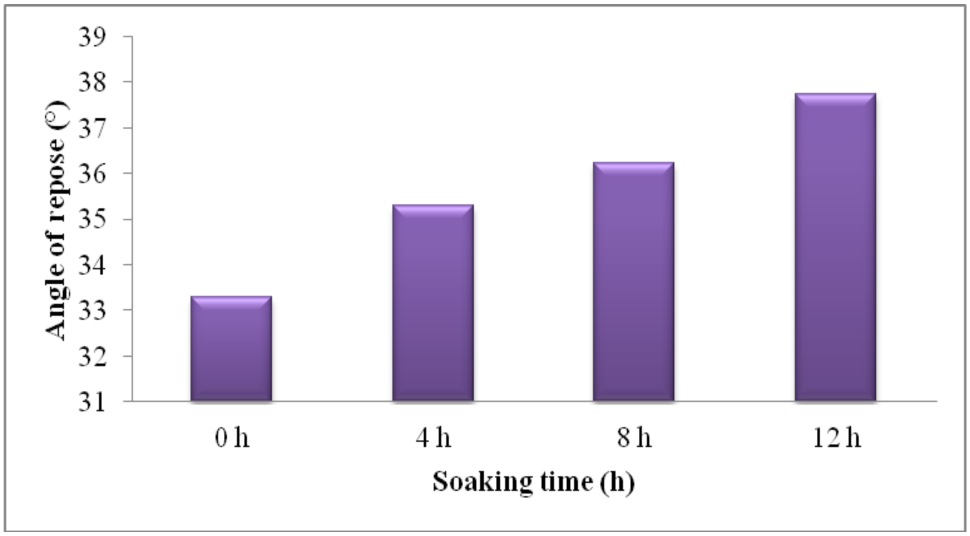

Fig.10 Effect of soaking time on angle of repose of field beans

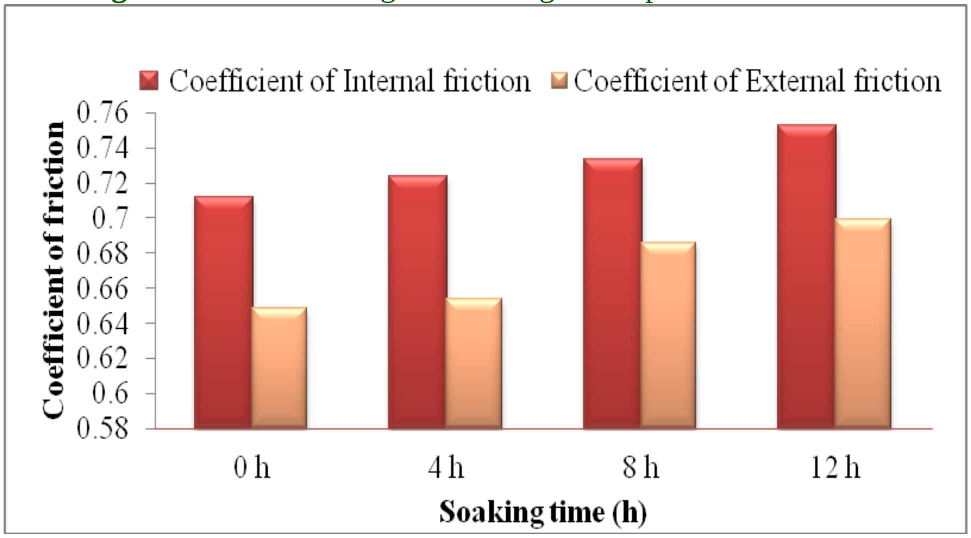

Fig.11 Effect of soaking time on coefficient of friction of field beans

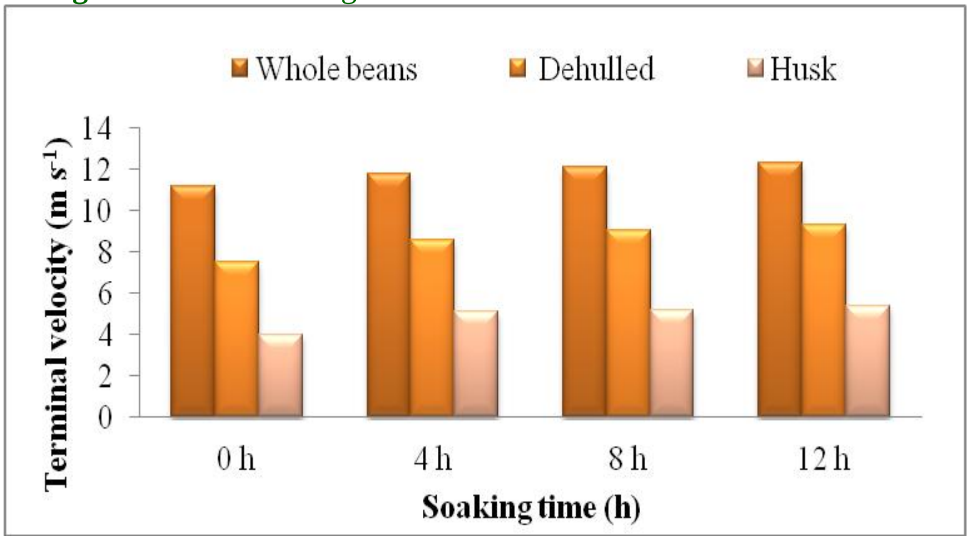

Fig.12 Effect of soaking time on terminal velocity of field beans

Plate.1 Field beans

Aerodynamic properties

The experimental results for the terminal velocity of field beans at various soaking time are plotted in Figure 12. The average values of terminal velocity of fresh and soaked (4, 8 , 12 hours) beans were found to be 11.20, 11.80, 12.13 and 12.33 m. s^{-1} for whole beans, 7.50, 8.56, 9.03 and 9.33 m. s^{-1} for dehulled beans and 4.00, 5.13, 5.20 and 5.40 m. s^{-1} for husk , respectively. The increase in terminal velocity with increase in moisture content was due to the increase in mass of an individual grain per unit frontal area presented to the air stream. The similar increasing trend in terminal velocity was reported by Nimkar and Chattopadhyay (2001) for green gram.

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