Moisture Dependent Physical and Frictional Properties of Mustard Seeds

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Abstract **- The physical and frictional properties of PBR-91 variety of Mustard seeds were evaluated as function of their moisture contents he geometric mean diameter, arithmetic mean diameter, sphericity , surface area, thousand seeds mass increased of PBR-91 variety of Mustard seeds from 1.61-1.92 mm, 1.58-1.92 mm, 0.921-0.991,8.14-11.58 mm^2 and 4.21 to 6.51 g respectively for the increase in the level of moisture from 6% to 18% (wet basis) where as these parameters for RLC-1 variety of Mustard seeds increased from 1.681-1.881 mm, 1.653-1.857 mm, 0.91-0.941, 8.968-11.109 mm^2 and 4.024-6.939 g respectively. The bulk density, true density and porosity decreased from 0.906-0.798 g/cc, 1.199-0.924 g/cc and 24.43-13.63% for PBR-91 variety where as these parameters for RLC-1 variety of Mustard seeds decreased from 0.890-0.785 g/cc, 1.275-0.954 g/cc and 30.19-17.77% respectively with increase in moisture content from 6 % to 18%(wet basis). The angle of repose for this variety was found to increase with increasing moisture content**

Keywords **- Moisture, sphericity, mustard seeds, true density, porosity**

I. Introduction

Mustard seed (Brassica napus L.) is bright yellow flowering member of the family Brassicaceae. Mustard is very widely cultivated throughout the world for the production of animal feed, vegetable fat for human consumption and biodiesel. Leading producers include the European Union, Canada, United States, Australia, China and India (Anonymous 2007).\

Mustard seed is an important fat plant since its seed contains 38-50% fat, 16-24% protein, and rich in oleic and linoleic acids and high boiling point of its fat (238ºC). Mustard oil has about 60% monounsaturated fatty acids of which 42% erucic acid and 12% oleic acid, it has 21% polyunsaturates of which 6% is the omega-3 alpha-linolenic and 15% omega-6 linoleic acid and it has 12% saturated fats (www.wikipedia.com) . It is one of the most heart –healthy fats and has been reported to reduce cholesterol levels, lower serum triglyceride levels, and keep platelets from sticking together.

The physical properties of rapeseeds, like those of other grains, are essential for the design of equipment for handling, harvesting, aeration, drying, storing, dehulling and processing. These properties are affected by numerous factors such as size, form, superficial characteristics and moisture content of the seed.

The objective of this study was to investigate some moisture-dependent physical properties of two varieties of mustard seeds. The parameters measured at different moisture content are Arithmetic mean diameter, Geometric mean diameter, Sphericity, Porosity, Surface area, Thousand seed mass, true density, Bulk density , Internal coefficient of friction and External coefficient of friction. These data will determine the behaviour of the rapeseeds during processing.

II. Materials And Methods

Seeds of PBR-91 and RLC-1 mustard varieties were employed in the present study. The average initial moisture content was found to be 10% (w.b.). The moisture content of the seeds was determined through an air convection oven drying the seeds at 103^{O}C. To raise the moisture content, a calculated predetermined quantity of water was added to samples which were then placed in sealed plastic bags and kept at room temperature for few days to let the moisture distribute uniformly throughout the samples. The quantity of water added was calculated through the following equation.

$$W_2 = W_1 \times \left[\frac{M_2 - M_1}{100 - M_2}\right]$$

Where, W_2= mass water to be added in gm, W_1=initial sample mass in gm, M_1=initial moisture content sample in % w.b. and M_2= desired moisture content in %. The physical properties were evaluated at five different moisture levels of 6, 9, 12, 15 and 18% for both the varieties (Tavakoli 2009).

1. Geometric mean diameter

Vernier Calliper having least count of 0.05 mm was used to measure geometric mean diameter. Three measurements namely maximum, intermediate and minimum mutually perpendicular dimensions of seeds were taken and the geometric mean diameter was measured as follows:

$$D_g = (LWT)^{1/3}$$

Where L, W, T are the maximum, intermediate and minimum mutually perpendicular dimensions respectively.

2. Arithmetic mean diameter

The average diameter of the seeds was calculated by using arithmetic mean of the three axial dimensions.

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

3. Sphericity

It is defined as the ratio of diameter of a sphere of same volume as that of the particle and the diameter of smallest circumscribing circle.

$$\Phi = \frac{(L + W + T)^{1/3}}{L}$$

4. Surface Area

The surface area of the seeds, S, was found by analogy with a sphere of the same geometric mean diameter, using the following relationship:

$$S = \Pi D_g^2$$

5. Bulk density

This represents the apparent density of particle. It was measured using a cylindrical container. The container was filled full with seeds and the weight of seeds was taken and bulk density was calculated by using the following formula:

$$\text{Bulk density} = \frac{Mass\ of\ seeds(kg)}{Volume\ of\ container(m^3)}$$

6. True density

True density represents the actual density of particle. It is defined as the ratio of mass of the material to its true volume. Importance of measuring true density is to calculate the space occupied by individual seed. It was determined by liquid displacement method. The liquid used was toluene. A measuring cylinder of 100 ml capacity was filled with seeds and the weight of seeds in that volume was noted down. Toluene was filled in the cylinder filled with seeds. The toluene displaced by the seed was noted down. True density was calculated as:

$$\text{True density} = \frac{\text{Mass of seeds (kg)}}{\text{Volume of toluene displaced by the seeds } (m^3)}$$

7. Porosity

It is defined as the percentage of volume of inters fruit space to the total volume of the fruit bulk. It was determined for the Mustard seeds by the following formula:

$$\text{Porosity } (\%) = \frac{(\text{True density} - \text{Bulk density})}{\text{True density}} \times 100$$

8. Thousand Seed mass

The mass of about 1000 seeds was measured using an electronic balance readable to 0.01 gm.

9. Frictional properties

The frictional properties of the Mustard seeds measured at five levels of moisture content were coefficient of internal friction, coefficient of external friction for plywood and GI sheet and angle of repose (Nimkar *et al* 2005).

9.1. Coefficient of internal friction

Coefficient of internal friction is the frictional resistance of seeds with each other. A small wooden box known as cell of dimension 10 cm x 10 cm x 3 cm was put into a larger wooden box known as a guided frame of dimensions 20 cm x 16 cm x 3.5 cm. The cell was tied with a fine copper wire attached to a fixed pulley. The other end of a copper wire was tied to a pan. The weight (W_1) was put on the pan so as to just slide the cell and the box together. Thereafter a fixed amount of sample of seeds of about 100 g (W) was put into the empty box and the cell was again placed into the box. The weight required to just slide the filled box and cell (W_2) was put on the pan. The coefficient of internal friction was calculated as:

$$\mu_i = \frac{W_2 - W_1}{W}$$

Where, μ_i = Coefficient of internal friction
W_1 = Weight required to slide empty box and cell
W_2 = Weight required to slide filled box and cell
W = Weight of seeds.

9.2. Coefficient of external friction

Coefficient of external friction is the frictional resistance between the seeds and the surface. A box of 20 cm x 16 cm x 3.5 cm was placed on a plywood surface and was tied to a copper wire. The copper wire was attached to the box. The wire was mounted on a pulley and the other end of the wire was attached to a pan. The weight (W_1) was put on the pan so as to just slide the cell and the box together. Thereafter a fixed amount of sample of seeds of about 100 g (W) was put into the empty box and the cell was again placed into the box. The weight required to just slide the filled box and cell (W_2) was put on the pan. The same procedure was followed for sliding on a GI sheet. The coefficient of external friction was calculated as:

$$\mu_e = \frac{W_2 - W_1}{W}$$

Where, μ_e = Coefficient of external friction
W_1 = Weight required to slide empty box
W_2 = Weight required to slide filled box
W = Weight of seeds.

3.3.3 Angle of repose

Angle of repose is the angle made with the horizontal at which the material will stand when piled. The angle of repose is also important in designing the equipment for mass flow and structures for storage (Davies 2009). The angle of repose was determined with a help of a cylinder arrangement. The cylinder was filled with the seeds up to the top and then slowly lifted, thus a conical heap was formed. The height and the base diameter of the heap were measured. The angle of repose was calculated as:

$$\alpha = \tan^{-1} \frac{2H}{D}$$

Where, α = Angle of repose
H = Height of the cone
D = Base diameter of the cone

III. Results And Discussions

The average values of geometric mean diameter, arithmetic mean diameter, sphericity and surface area for both varieties at different moisture content are shown in table 1.The bulk density, true density ,porosity and thousand seed mass reading are given in table 2 where as frictional parameters are represented in table 3.

The geometric mean diameter for PBR-91 ranged between 1.61 and 1.92 whereas for RLC-1 it was found to be from 1.68 to 1.88.The arithmetic mean diameter for both the varieties increased in PBR-91 it increased from 1.58 to 1.92 and in RLC-1it varied from 1.65 to 1.85. From Fig.1 and Fig.2 it can be observed that the geometric mean diameter and arithmetic mean diameter for PBR– 91 and RLC– 1 varieties of Mustard seeds increased with increase in moisture content due to increase in linear dimensions with increasing trend of moisture content.

The sphericity increased with increasing trend of moisture content for PBR– 6 it was from 0.921 to 0.991 and inRLC–1it ranged from0.910 to0.941 as shown in Fig. 3. This might be due to the fact that as the moisture content increased the shape of the seeds approaches to sphere. The surface area for both the varieties was found to increase with increase in moisture content due to increase in size of the seeds due to moisture absorption (Fig.4).In PBR-91 it increased from 8.14 to 11.58 and in RLC-1 it was found to be from 8.90 to 11.10.

VARIETY	M.C (%)	GEOMETRIC MEAN DIAMETER (mm)	ARITHMETIC MEAN DIAMETER (mm)	SPHERICITY	SURFACE AREA (mm^2)
PBR-91	6	1.61	1.58	0.921	8.14
	9	1.74	1.74	0.954	9.51
	12	1.83	1.82	0.965	10.52
	15	1.89	1.85	0.969	11.22
	18	1.92	1.92	0.991	11.58
RLC-1	6	1.68	1.65	0.910	8.90
	9	1.74	1.73	0.924	9.50
	12	1.79	1.77	0.935	10.07
	15	1.83	1.81	0.938	10.59
	18	1.88	1.85	0.941	11.10

Table1: Geometric properties of seeds at different moisture levels.

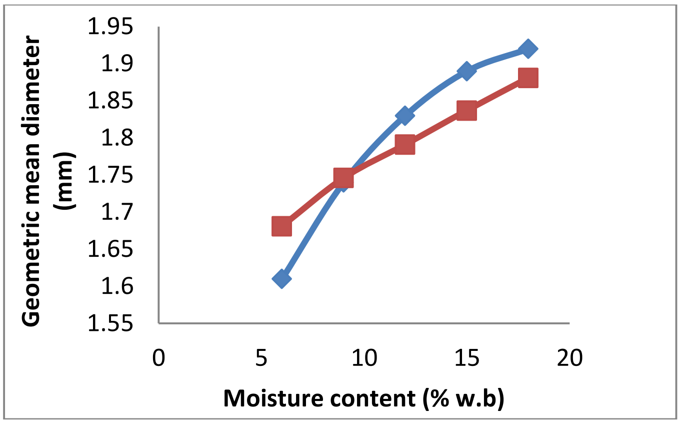

Fig. 1: Effect of moisture content on geometric mean diameter

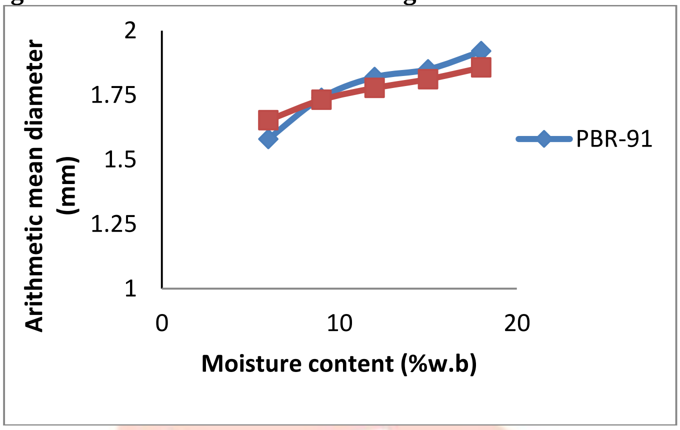

Fig.2: Effect of moisture content on arithmetic mean diameter

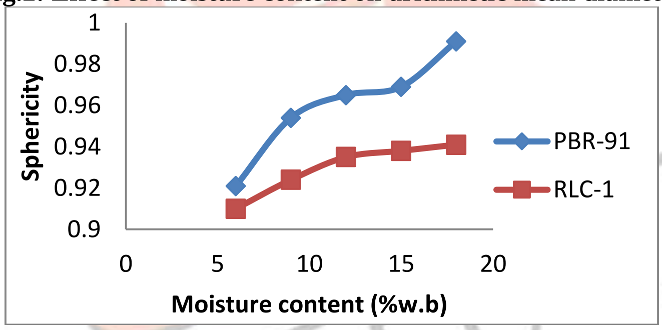

Fig.3: Effect of moisture content on sphericity

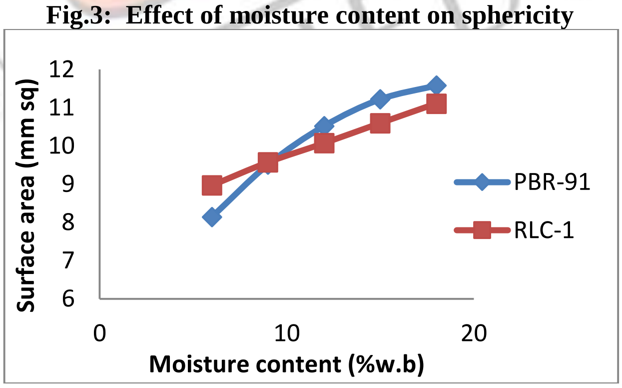

Fig. 4: Effect of moisture content on surface area

VARIETY	M.C (%)	BULK DENSITY (g/cc)	TRUE DENSITY (g/cc)	POROSITY (%)	MASS OF 1000 SEEDS
PBR-91	6	0.906	1.199	24.43	4.21
	9	0.860	1.123	23.41	5.10
	12	0.847	1.056	19.79	5.95
	15	0.823	0.983	16.27	6.26

	18	0.798	0.924	13.63	6.51
RLC-1	6	0.890	1.275	30.19	4.02
	9	0.880	1.250	29.6	4.24
	12	0.840	1.143	26.5	5.67
	15	0.815	1.045	22.00	6.23
	18	0.785	0.954	17.77	6.93

Table2: Bulk density, true density, porosity and thousand seed mass of seeds at different moisture levels.

The bulk density for both the varieties was found to decrease with increasing moisture content as shown in Fig.5. In PBR-91 it was observed to decrease from 0.906 to 0.798 and in RLC-1 it ranged from 0.890 to 0.785.The decrease in bulk density with increasing moisture content might be due to the increase in mass owing to moisture gain in the sample was lower than accompanying volumetric expansion of the bulk. The true density also showed a decrease with increase in moisture for PBR– 91 and RLC-1 varieties as shown in Fig.6.

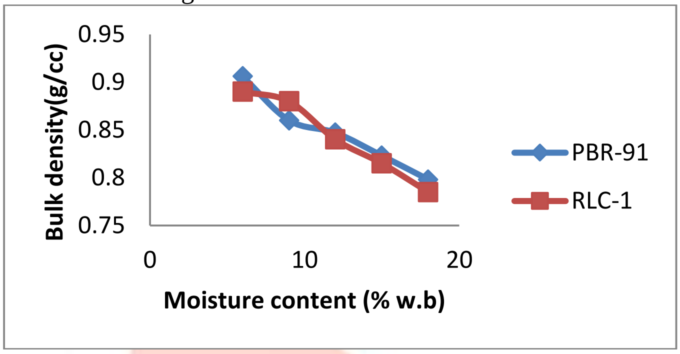

Fig. 5: Effect of moisture content on bulk density

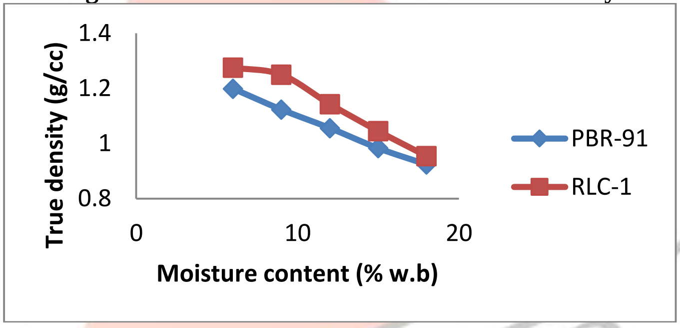

Fig. 6: Effect of moisture content on true density

The porosity decreased from 24.43 to 13.63 in PBR-91 and 30.19 to 17.77 in RLC-1 with increase in moisture content as shown in Fig.7. This was mainly due to the fact that with increase in moisture the volume of the seeds increased and number of seeds per unit volume decreased.

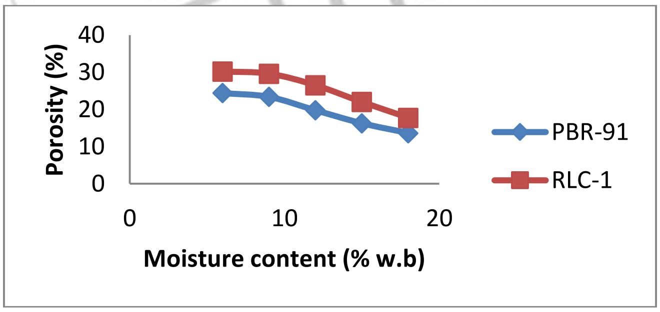

Fig.7: Effect of moisture content on porosity

The thousand increased with moisture as shown in Fig.8. This was due to the reason that as the seed absorbs moisture its weight increases. In PBR-91 it increased from 4.21 to 6.51 whereas in RLC-1 it was observed to vary from 4.02 to 6.93.

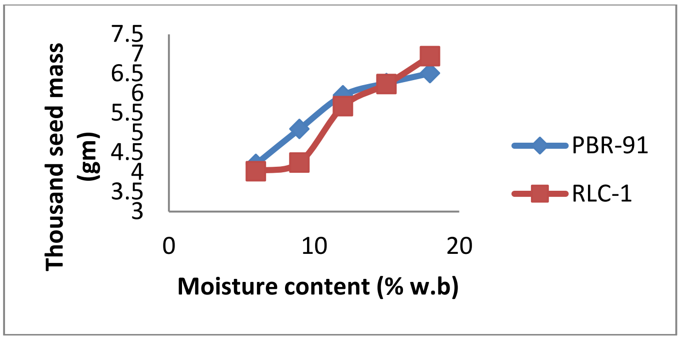

Fig.8: Effect of moisture content on thousand seeds

The coefficient of internal friction showed an increase from 1.024 to 1.789 in PBR-91 and 1.001 to 1.514 for RLC-1 as moisture content was increased from 6 to 18% w.b. as shown in Fig.9. This was due to the reason that as the moisture in the seeds was increased, the cohesive force at the surface of contact increased.

VARIETY	M.C (%)	Coefficient of internal friction	Coefficient of external friction		Angle of repose (degree)
			Plywood	GI sheet	
PBR-91	6	1.024	0.306	0.298	26.8
	9	1.166	0.317	0.314	27.56
	12	1.277	0.325	0.319	27.97
	15	1.698	0.348	0.339	28.35
	18	1.789	0.366	0.358	28.95
RLC-1	6	1.001	0.255	0.251	26.35
	9	1.098	0.261	0.257	26.53
	12	1.178	0.272	0.264	26.81
	15	1.310	0.295	0.274	27.09
	18	1.514	0.317	0.314	27.3

Table 3: Frictional properties of seeds

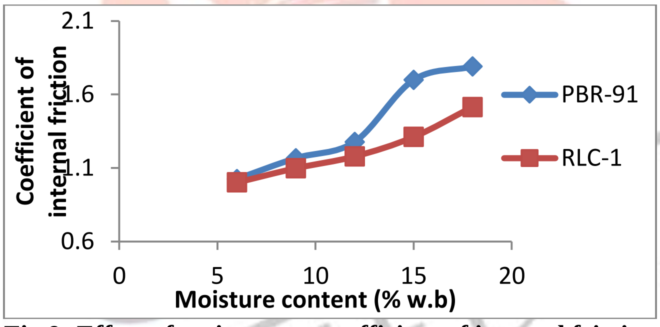

Fig.9: Effect of moisture on coefficient of internal friction

The coefficient of external friction for plywood and GI sheet for both the varieties increased with increase in moisture as shown in Fig.10 and Fig.11. This was mainly due to the reason of increase in resistance offered by the surface to the seeds at higher moisture content.

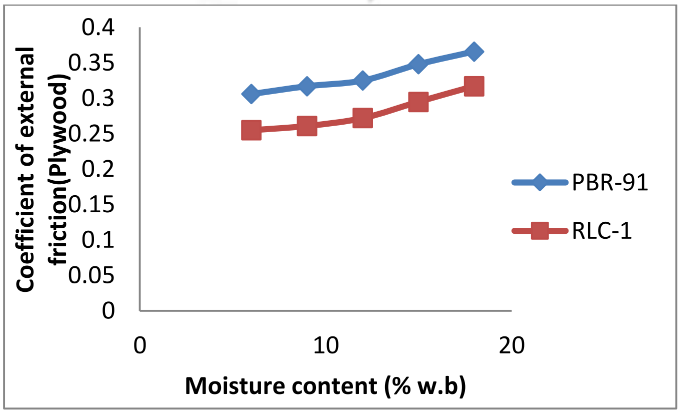

Fig.10: Effect of moisture on coefficient of external friction (plywood)

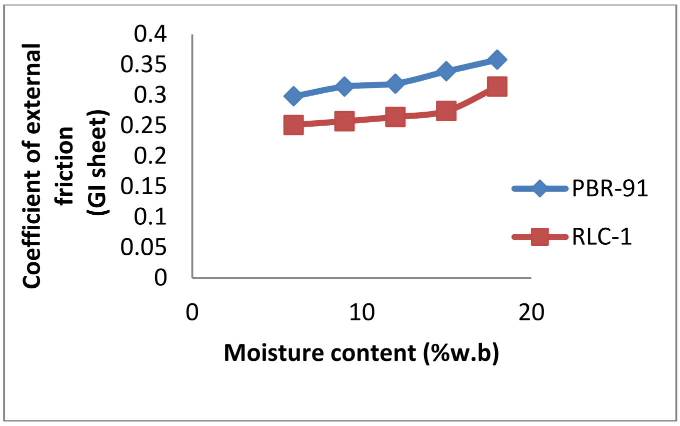

Fig.11: Effect of moisture on Coefficient of external friction (GI sheet)

The angle of repose increased with increase in moisture, for PBR-91 it increased from 26.8 to 28.95 whereas in RLC-1 it increased from 26.35 to 27.3 as shown in Fig.12. This could be might be because of the reason that with increasing moisture the sticky behavior of the seeds increases that hold the seeds together.

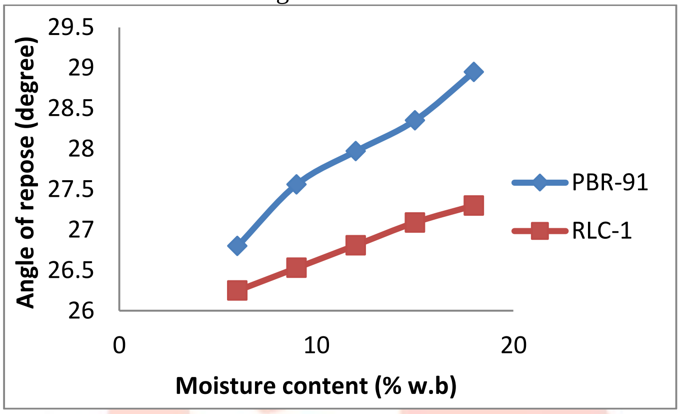

Fig.12: Effect of moisture on angle of repose.

IV. Conclusions

The present study was undertaken to determine the engineering properties of Mustard seeds at different levels of moisture content. The physical properties of Mustard seeds varied from variety to variety and these were the functions of the seed moisture content.

The geometric mean diameter, arithmetic mean diameter, sphericity , surface area, thousand seeds mass increased of PBR-91 variety of Mustard seeds from 1.61-1.92 mm, 1.58-1.92 mm, 0.921-0.991,8.14-11.58 mm^2 and 4.21 to 6.51 g respectively for the increase in the level of moisture from 6% to 18% (wet basis) where as these parameters for RLC-1 variety of Mustard seeds increased from 1.681-1.881 mm, 1.653-1.857 mm, 0.91-0.941, 8.968-11.109 mm^2 and 4.024-6.939 g respectively. The bulk density, true density and porosity decreased from 0.906-0.798 g/cc, 1.199-0.924 g/cc and 24.43-13.63% for PBR-91 variety where as these parameters for RLC-1 variety of Mustard seeds decreased from 0.890-0.785 g/cc, 1.275-0.954 g/cc and 30.19-17.77% respectively with increase in moisture content from 6 % to 18%(wet basis).

The coefficient of internal friction and coefficient of external friction for PBR-91 variety increased from 1.024-1.789 and 0.306-0.366 respectively on plywood surface and for GI sheet 0.298-0.358 for increase in the moisture from 6 to 18 % (wet basis). The angle of repose for this variety was found to increase with increasing moisture content. However the coefficient of internal friction increased from 1.001-1.514, coefficient of external friction for plywood surface a GI sheet surface increased from 0.255-0.317 and 0.251-0.314 and angle of repose increased for both the varieties with increase in moisture content from 6% to 18% (wet basis).

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