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RESEARCH PAPER

Engineering properties of red gram (*Cajanus cajan*)

Kalay Khan*, S. C. Moses[1] **and** Padam Singh[2]
College of Agricultural Engineering and Technology (SKUAST), Shalimar, Srinagar (J&K) India
(Email: khan.kalay93@gmail.com)

Abstract : Engineering properties of red gram are important for designing the seed hopper food processing equipments and storage bin. Physical and mechanical properties of red gram as a function of moisture content in the range of 10.10 to 20 % (d.b). The average length, width, thickness, geometric mean diameter, sphericity, thousand grains weight and angle of repose ranged from 6.90 to 8.40 mm, 5.10 to 7.90 mm, 4.10 to 6.30 mm, 6.50 to 7.70 mm, 0.85 to 0.92, 97.30 to 105.30 g and 27.30 to 29.10° as the moisture content increased from 10.10 to 20 per cent d.b., respectively.

Key Words : Red gram, Moisture content, Engineering properties, Seed hopper

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INTRODUCTION

Red gram is the II[nd] important pulse crop after the gram and a major *Kharif* crop in the country. India ranks I[st] in area and production in the world with 80 per cent and 67 per cent of world's acreage and production, respectively. Highest production of red gram is from Maharashtra which is around 30 per cent of National Production.

(Directorate of Pulses Development, Bhopal) its actual place of origin is very controversial as some people believe, it originated in India, while others say, it originated in Africa. According to Vavilov (1928), genus Cajanus originated in the Hindustan. As per Van Der Maesen (1980) also, the centre of origin of the crop is India. According to Bentham (1861) and De Candolle (1886), it originated in Africa.

Red gram also plays an important role in sustaining soil fertility by improving physical properties of soil and fixing atmospheric nitrogen. Being a drought resistant crop, it is suitable for dry land farming and predominantly used as an intercrop with other crops (Gopalan *et al.*, 1971). Knowledge of physical properties such as size, shape, mass, surface area, volume, thousand grain weight, sphericity, bulk density, true density and porosity are necessary for the effective and proper design of various separating, handling and drying equipment (Pandiselvam *et al.*, 2015). Length, width, thickness, volume and sphericity of pulses are important for screening of solids to separate foreign material and sorting of various sizes of seeds and seed metering device. Bulk and true density of agricultural material play an important role in design of silos and storage bins. Angle of repose plays an important role in designing an

*** Author for correspondence:**
[1]Sam Higginbottom Institute of Science and Technology, Allahabad (U.P.) India
[2]College of Forestry, Veer Chandra Singh Garhwali Uttarakhand University of Horticulture and Forestry, Ranichauri, Tehri Garhwal (Uttrakhand) India

equipment for solid flow and storage. Knowledge on the frictional properties is valuable in designing the machines for dehulling and packaging (Niveditha *et al.*, 2013). Therefore, the present study was conducted to determine physical properties of red gram (APK-1) as a function of moisture content from 10.10 to 20 per cent (d.b), which is essential for designing and fabrication of seed metering device and seed box of multi crop planter.

MATERIAL AND METHODS

Red gram seeds were collected from Alopi Bagh Market, Allahabad (U.P.). The seeds were cleaned manually in order to remove the impurities such as dust, stone, sticks, immature, damaged kernels and ensured that the samples were free from broken and immature ones and other foreign materials. The cleaned kernels were stored in a high density poly-ethylene sheet for further usage. The initial moisture content of the seeds was determined by drying samples in a hot air oven at 103±1^{o}C for 24 h until a constant weight was reached (AOAC, 2000). In the Indian pulse milling and storage industry, generally green grams are received at different moisture content (10 to 25%) based on the climatic conditions and processed by adopting a grain size criterion (Nimkar and Chattopadhyay, 2001). Hence, this study was conducted at a moisture content of 10.10 to 20 per cent (d.b.).

Samples of different moisture level *viz.*, 10.10, 13.70, 16.30 and 20 per cent (d.b.) were prepared by sprinkling a calculated amount of water over the red gram with constant stirring by hand. The conditioned samples were placed into polyethylene bags to prevent further moisture loss. The sample bags were kept at 5^{o}C temperature in a refrigerator for 5 days to enable the moisture to distribute uniformly throughout the sample. The required quantity of sample was withdrawn from the refrigerator and equilibrated to room temperature (31±3°C) before conducting different tests (Ravi *et al*., 2014).

Firstly, twenty grains were randomly selected for three dimensions like length (major diameter), width (intermediate diameter) and thickness (minor diameter).

Size:

The size of the seed was specified by length, width and thickness. The axial and lateral dimension of the seeds was measured by using Vernier Caliper (least count 0.01).

Shape:

This parameter of seed was relevant to design of seed metering device and seed hopper. The shape of the seed was expressed in term of roundness and sphericity.

Roundness:

A seed was selected randomly and its dimension was taken by using image analysis method in natural rest position. The area of smallest circumscribing circle was calculated by taking the largest axial dimension of seed at natural rest position as the diameter of circle. The per cent roundness was calculated as follow:

$$R_p = \frac{A_p}{A_c} \times 100$$

where,

R_p = Per cent roundness

A_p = Projected area, mm^2

A_c = Area of smallest circumscribing circle, mm^2.

Sphericity:

The sphericity is a measure of shape character compared to a sphere of the same volume. Assuming that volume of solid is equal to the volume of tri-axial ellipsoid with intercepts a, b, c and that the diameter of circumscribed sphere is a largest intercepts of the ellipsoid, the degree of sphericity was calculated as follows (Mohsenin, 1986):

$$DS = \frac{(a \times b \times c)^{1/3}}{a}$$

where,

DS = Degree of sphericity

a = Largest intercept, mm

b = Largest intercept normal to a, mm

c = Largest intercept normal to a and b, mm.

Bulk density:

A wooden box with inside dimension of 10 x 10 x 10 cm was used for the measurement of bulk density of red gram seeds. The box was filled with seeds without compaction and then weighed. The bulk density was calculated as follow (Singh *et al*., 2019):

$$BD = \frac{W}{V}$$

where,

BD = Bulk density, g/cm^3

W = Weight of seeds, g

V = Volume of wooden box, cm^3

Volume and true density:

Toluene displacement method was used to determine the volume and true density of each crop seed. A sample of 100 seeds was weighed. The sample was immersed in a jar containing toluene displaced by the sample was recorded, thus, volume of single seed was calculated. True density was calculated as the ratio of weight of the sample to its volume.

$$\text{True density} = \frac{\text{Weight of grain (g)}}{\text{True volume occupied by the same grains (cm)}^3}$$

Porosity:

The porosity of the red gram seeds were calculated by the following eq.

$$\text{Porosity (\%)} = (1 - \frac{BD}{TD}) \times 100$$

where,

BD = Bulk density, g/cm^3

TD = True density.

Angle of repose:

The angle of repose of the grains used for designing the hopper of multi crop planter. A box having circular platform fitted inside was filled with different grains. The circular platform was surrounded by a metal funnel leading to a discharge hole. The extra grains surrounding the platform were removed through discharge hole leaving a free standing cone of red gram grains on the circular platform. A stainless steel scale was used to measure the height of cone and angle of repose was calculated by the following formula:

$$\Phi = \tan - (\frac{2h}{d})$$

where,

Φ = Angle of repose, degrees

h = Height of cone, cm

d = Diameter of cone, cm.

Co-efficient of static friction:

The co-efficient of static friction was measured by using inclined plane method on mild steel surface. The seed was kept separately on a horizontal surface and the slope was increased gradually. The angle at which the materials started to slip was recorded. The co-efficient of static friction was calculated by using the following formula (Singh *et al.*, 2015):

Co-efficient of static friction = tan c

where,

Φ = Angle of static friction, degrees.

Thousand seed weight:

One thousand seed weight of red gram seeds was weighing on a digital weighing balance.

RESULTS AND DISCUSSION

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

Size distribution pattern:

The average values of the three dimensions of red gram seed such as length, width and thickness were determined in this study at different moisture content are shown in Table 1. It is observed from the table that each dimension was linearly dependent on the moisture content of the seed. A very high correlation was found between the length, width and thickness and moisture content

Table 1: Physical properties of red gram seeds at different moisture content

Moisture content % d.b.	Length, mm	Width, mm	Thickness, mm		Geometric mean diameter, mm	
10.10	6.90	5.10	4.10		6.50	
13.7	7.10	5.85	4.90		6.90	
16.30	7.90	6.20	5.40		7.25	
20	8.4	7.90	6.30		7.70	
Mean	7.57	6.26	5.17		7.08	
Moisture content % d.b.	Bulk density (kg/cm^3)	True density (kg/cm^3)	Angle of repose	Co-efficient of static friction	1000 kernel weight (g)	Sphericity
10.10	680	1020	27.30	0.38	97.30	0.85
13.7	650	1070	27.90	0.45	100.5	0.92
16.30	610	1090	28.30	0.65	102.5	0.94
20	540	1170	29.10	0.80	105.30	0.97
Mean	6.20	1087.5	28.15	0.57	101.4	0.92

representing the effect of moisture absorption. The red gram expanded in length, width and thickness as the moisture content increased from 10.10 to 20 per cent d.b. The length, width and thickness of the red gram seeds varied from 6.90 to 8.40 mm, 5.10 to 7.90 mm and 4.10 to 6.30 mm, respectively. Results were in agreement with the earlier findings for soybean (Kulkarni *et al*., 1993 and Deshpande *et al.,* 1993) and for black gram (Munde, 1999).

Geometric mean diameter:

Geometric mean diameter of red gram seeds at different moisture contents are described in Table 1. The average geometric mean diameter increased from 6.50 to 7.70 mm ($P < 0.08$), as the moisture content increased from 10.10 to 20 per cent d.b. The increase in geometric mean diameter with increase in moisture content was found for onion seeds (Pandiselvam *et al.,* 2014). The changes in the geometric mean diameters of red gram with increase in moisture content might be due to swelling of grains by absorbing moisture.

Sphericity:

Sphericity of red gram seeds also increased linearly with increasing moisture content (Table 1). It was calculated at different moisture contents exhibiting a change from 0.85 to 0.97. The increase in sphericity of red gram was found statistically significant ($P < 0.07$) as the moisture content increased from 10.10 to 20 per cent d.b. The results were similar to those reported for soybean and rice grains by Kulkarni *et al*. (1993) and Pandiselvam *et al.* (2015a), respectively.

Thousand seed weight:

The weight one thousand grain of red gram at different moisture contents varied from 97.30 to 105.30 g ($P < 0.01$) as the moisture content increased from 10.10 to 20 % d.b. (Table 1). The increase in thousand grain weight with increase in moisture content might be due to increase in water content of red gram. Similar results have been reported for soybean (Deshpande *et al.,* 1993) black gram (Munde, 1999) and paddy (Ravi and Venkatachalam, 2014).

Bulk and true densities:

The bulk and true densities of red gram seeds at different level moisture are shown in Table 1. The bulk density (ρb) decreased with the increase in moisture content. It decreased from 680 to 540 kg/cm^3 ($P < 0.01$) with an increase in moisture content from 10.10 to 20 per cent d.b. The decrease in bulk density for green gram with increase in moisture content indicated that the increase in mass owing to moisture gain in the grain sample was lower than the accompanying volumetric expansion of the bulk. Similar results have been reported for chickpea (Dutta *et al*., 1988), soybean (Deshpande *et al.,*1993), moth gram (Nimkar *et al*., 2005) and black gram (Theertha *et al*., 2014).

True density of red gram seeds increased linearly with increase in moisture content which presented in Table 1. It increased from 1020 to 1170 kg/ cm^3 ($P < 0.05$) with an increase in moisture content from 10.10 to 20 per cent d.b. This increase indicated that there is a higher grain mass increase in comparison to its volume increase as its moisture content increases. This agrees with finding of Aviara *et al.* (1999) for guna seeds Selvi *et al.* (2006) for linseed, Gupta and Das (1997) for sunflower seeds and Yalcin and Ozarslan (2004) for vetch seed and Pandiselvam *et al.* (2015a) for rice grains.

Angle of repose:

Angle of repose of seed is very important for design seed hopper *i.e.* the red gram moisture content in range from 10.10 to 20 per cent d.b. is described in Table 1. The angle of repose increased with an increase in moisture content. It increased from 27.30 to 29.10^o ($P > 0.01$) with an increase in moisture content from 10.10 to 20 per cent d.b. These similar results were reported by Deshpande *et al.* (1993); Amin *et al.* (2004); Pandiselvam *et al*. (2014) and Theertha *et al*. (2014) for soybean, lentil, onion seed and black gram, respectively.

Co-efficient of static friction:

The co-efficient of friction of red gram seeds against test galvanized iron is described in Table 1. From the Table 1, it is shown that the static co-efficient of friction of green gram increased from 0.38 to 0.80 on galvanized iron at different level of moisture range from 10.10 to 20 per cent d.b., respectively. Increase in co-efficient of static friction of red gram seed at higher moisture content might be due to higher cohesive force between grains as well as between grains and test surfaces (Pandiselvam *et al.,* 2014). Similar results were reported by Munde (1999) and Ashwini (2014) for black gram and ridge gourd seed, respectively, which confirmed the findings of present study.

Conclusion:

From the investigations the values of average length, width, thickness, geometric mean diameter, sphericity, thousand grains weight and angle of repose ranged from 6.90 to 8.40 mm, 5.10 to 7.90 mm, 4.10 to 6.30 mm, 6.50 to 7.70 mm, 0.85 to 0.92, 97.30 to 105.30 g and 27.30 to 29.10° as the moisture content increased from 10.10 to 20 per cent d.b., respectively.

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