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Effect of moisture content on physical properties of black gram (*Vigna mungo*)

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Abstract
Physical properties were determined. Different physical properties, viz. size in terms of length, width and thickness were determined for fifty grains as well as sphericity, bulk density, porosity, true density, and an angle of repose were also determined for black gram at the moisture content of 10.18 (± 0.089), 11.46 (± 0.446), 12.22 (± 0.131) and 13.86 (± 0.071) (w b) respectively. Major axis L (mm) 04.36 (00.116), 04.57 (00.084) 04.74 (00.175) and 05.03 (00.060) and minor axis T (mm) 03.49(00.10), 03.67(00.10), 03.78 (00.09) and 03.83 (00.07) respectively. Geometric mean diameter (mm) 03.92(00.070), 04.10(00.060), 04.23(00.072), 04.35(00.051) and Sphericity (%) 00.90(00.020), 00.89(00.016), 00.89(00.022) and 00.86(00.010) respectively. Test weight [1000 grain wt. (g)] was 49.05(00.485), 49.87(00.075) 50.72(00.188) and 51.83(00.946). Bulk density (g/cc) 00.78(00.002), 00.77(00.001), 00.77(00.001) and 00.76(00.002) and true density (g/cc) 01.33(00.019), 01.32(00.020) 01.31(00.027) and 01.30(00.024) respectively. Porosity (%) 41.56 (00.852), 41.59(00.994), 41.29(01.139) and 40.95(01.172). Angle of repose (degrees) 27.70 (00.675), 28.44 (00.726) 28.66 (00.500) and 29.20 (00.421) Terminal velocity (m/s) 10.32(00.052), 10.47(00.051) 10.64(00.062) and 10.70 (00.421).

Keywords: Triclosan, TCS, determination, detection, sensor

Introduction

The word "Pulse" is derived from the Latin word "Pulse" meaning pottage i.e. seeds boiled to make porridge or thick soup (Singh *et al*. 2018). Pulses are the cheapest source of dietary proteins. The high content of protein in pulses makes the diet more nutritive. It is supplementary protein in daily diets based on cereals and food for predominantly vegetarian population and for those who cannot afford expensive animal protein, It often regarded as poor men's meat (Mangaraj *et al*., 2013). In order to design equipment for the handling, conveying, separation, drying, aeration, storing and processing of bean seeds, it is necessary to determine their physical properties. 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. Dimensions are important to design the cleaning, sizing and grading machines. Coefficient of friction is important in designing equipment for solid flow and storage structures. The coefficient of friction between seed and wall is an important parameter in the prediction of seed pressure on walls (Amin *et al*., 2004) [4] Engineering properties of granular agro-materials are important in terms of the machines and storage facilities designing. Bulk density, true density, porosity and the static coefficient of friction can be useful in sizing grain hoppers and storage facilities (Varnamkhastia *et al.*, 2007). These properties are important in the construction of bulk storage facilities and the calculation of the dimensions of intermediate holding bins of a given capacity. Problems associated with design should not be attributed to disagreement among design philosophies, but rather to a serious lack of understanding of certain grain properties and how they relate to bin design (Thompson and Ross, 1983). India is the leading pulse producing country in the world based on 04th Advance Estimates India produce 25230.00 thousand tonnes pulse in year 2017-18, The production of black gram was 3560 thousand tones that are 14.11 per cent of share in total production in India (Anonymous, 2018) [1]. Physical properties of grain and premilling treatments play an important role to determine the dehulling quality therefore physical properties were determined. Different physical properties, viz. size in terms of length, width and thickness were determined for fifty grains as well as sphericity, bulk density, porosity, true density, and an angle of repose were also determined for black gram replicated ten times. The data was described in the subsequent sections hereunder.

Material and method

Black gram and green gram seed size

Black gram seed size was measured by using (Mohsenin, 1986) [10].

$$\text{Size} = (L \times B \times T)^{1/3}$$

B = breadth (along medium axis), mm
T= thickness (along minor axis), mm

Sphericity

The sphericity (Ø) was found out by using the (Moshenin, 1986) [10].

$$Ø = \frac{(L\,B\,T)^{1/3}}{L}$$

Where,
$(L\,B\,T)^{1/3}$ = geometric mean diameter
L, B, T = semi-axis of major, medium and minor axis of the seed.

The values of sphericity were calculated individually by using the data on geometric mean diameter and the major axis of the grain.

Thousand grains mass

Thousand grains mass was determined by counting 1000 grains and weighing them through a digital electronic balance (CONTECH, Model No: CT-300. SERIAL No. - 1200078) having an accuracy of ± 0.001 g 2 (Shirkole *et al.* 2011) [18]

Bulk density

The bulk density of the black gram and green gram grains were determined by using the standard test weight procedure, by filling a container of 500 ml with the grains from a height of 150 mm at a constant rate and then weighing the content. No separate manual compaction of grains was done. The bulk density was calculated from the mass of grains divided by the volume of the grain. The bulk density was expressed in g / cc (Kibar, 2010) [9]

$$\text{Bulk density} = \frac{W}{V}$$

Where,
W = Mass of grains, g
V = Volume occupied by the same grains, cc

True density

The true density of black gram and green gram grains was defined as the ratio of the mass of the sample to the true volume of the same sample. True density was determined by the liquid displacement method using toluene (Mohsenin, 1986) [10], as it has little tendency to penetrate into the grains. Black gram and green gram grains will not absorb toluene within the short time. True density of toluene was 0.87 g/cc. The volume of toluene displaced was found by immersing a weighed quantity of black gram and green gram grains in toluene. True density was calculated using the following formula. The measurement of true density was replicated ten times and is expressed in g/cc.

$$\text{True density, } \rho t = \frac{W_t}{V_t}$$

Where,
W_t = Mass of grains, g
V_t = True volume occupied by the same grains, cc

Porosity

The porosity of black gram and green gram grains of selected levels of moisture content was calculated from the values of bulk and true densities using the formula as described by Mohsenin (1986) [10].

$$\text{Porosity} = \left(1 - \frac{\rho_b}{\rho_t} \times 100\right)$$

Where,
ρ_b = Bulk density
ρ_t = True density

Angle of repose

The angle of repose of black gram and green gram grains was determined by standard circular platform method as given by Mohsenin (1986) [10]. A box having circular platform fitted inside was filled with black gram and green gram. The circular platform was surrounded by a metal funnel leading to a discharge hole. The extra grains surrounding the circular platform were automatically discharged through the funnel leaving a free-standing cone of black gram and green gram grains on the platform. A stainless steel scale was used to measure the height of cone and angle of repose was calculated by the following equation

$$\theta = \tan^{-1}\left(\frac{2h}{d}\right)$$

Where,
θ = Angle of repose, º C
h = Height of cone, cm
d = Diameter of cone, cm

Terminal velocity

The terminal velocity of the grain at different moisture contents were 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 and 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 airflow rate was gradually increased till the grain mass gets suspended in the air stream. Air velocity near the location of grain suspension was measured using a constant temperature- type anemometer having a least count of 0.1 m/ s. (Shirkole *et al.* 2011) [18]

Result and Discussion

The various observation were recorded at the moisture content of 10.18 (± 0.089), 11.46 (± 0.446), 12.22 (± 0.131) and 13.86 (± 0.071) (w b) respectively. The average values of observation are given in Table. 1

Table 1: Physical properties of black gram at different moisture contents

S.N	Particulars	Moisture content % (w b)			
		10.18	**11.46**	**12.22**	**13.86**
1	Major axis L (mm)	04.36 (00.116)	04.57 (00.084)	04.74 (00.175)	05.03 (00.060)
2	Minor axis T (mm)	03.49 (00.10)	03.67 (00.10)	03.78 (00.09)	03.83 (00.07)
3	Geometric mean diameter (mm)	03.92 (00.070)	04.10 (00.060)	04.23 (00.072)	04.35 (00.051)
4	Sphericity (%)	00.90 (00.020)	00.89 (00.016)	00.89 (00.022)	00.86 (00.010)
5	Test weight [1000 grain wt. (g)]	49.05 (00.485)	49.87 (00.075)	50.72 (00.188)	51.83 (00.946)
6	Bulk density (g/cc)	00.78 (00.002)	00.77 (00.001)	00.77 (00.001)	00.76 (00.002)
7	True density (g/cc)	01.33 (00.019)	01.32 (00.020)	01.31 (00.027)	01.30 (00.024)
8	Porosity (%)	41.56 (00.852)	41.59 (00.994)	41.29 (01.139)	40.95 (01.172)
9	Angle of repose (degrees)	27.70 (00.675)	28.44 (00.726)	28.66 (00.500)	29.20 (00.421)
10	Terminal velocity (m/s)	10.32 (00.052)	10.47 (00.051)	10.64 (00.062)	10.70 (00.421)

* Figures in parenthesis are corresponding ± S.D. values

Dimensions

The dimensions *viz.*, major (L) and minor (T) axis were measured for randomly selected 50 grains and averages are presented in Table 1 for black gram grains sample. At the moisture content of 10.18 (± 0.089), 11.46 (± 0.446), 12.22 (± 0.131) and 13.86 (± 0.071) (w b) and 11, 13, 14 and 16 (d b) respectively. The major axis values were found to be 4.362 (± 0.116), 4.577 (± 0.084), 4.743 (± 0.175) and 5.033 (± 0.060) mm respectively and minor axis value were found to be 3.49 (± 0.10), 3.67 (± 0.10), 3.78 (± 0.09), 3.83 (± 0.07) mm respectively. As moisture content increased the dimension of the major axis and minor axis also increased. The increase in the dimensions are attributed to expansion or swelling as a result of moisture uptake in the intracellular spaces within the pulse grain. This shows that there was positive relationship between moisture content and axial dimensions of grain. Similar results for different granular agro-materials have been reported by Nimkar and Chattopadhyay (2002) for green gram, Tabatabaeefar (2003) [19] for wheat, Bo Wang *et al.* (2007) [5] for fibered flaxseed, Ozturk and Esen (2008) [13] for barley, Kibar (2010) [9] for different rice varieties and Shirkole *et al.* (2011) [18] for soybean.

Geometric mean diameter

The geometric mean diameter of the black gram increased linearly with increase in moisture content in Fig.1 and Table 1. This indicates that relatively proportional change occurred in the dimension of black gram. Similar trend have been reported by Kibar (2010) [9] for different rice varieties.

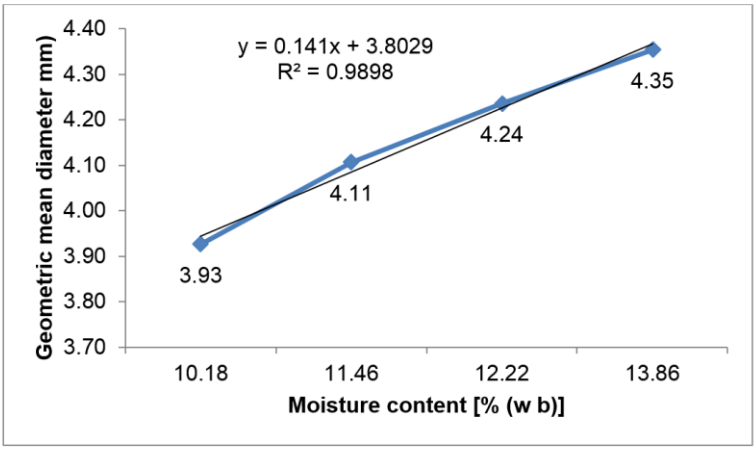

Fig 1: Effect of various moisture contents on geometric mean diameter of black gram grain

Sphericity

The sphericity of the black gram grain was found to be decreased linearly with increase in moisture content Fig. 2 (Table 1). Similar trends for different granular agro-materials have been reported by Kibar (2010) [9] for different rice variety and Shirkole *et al.* (2011) [18] for soybean.

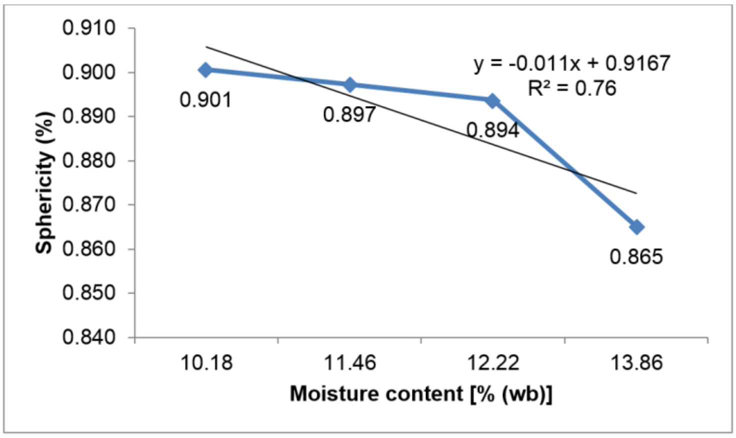

Fig 2: Effect of various moisture contents on sphericity of black gram grain

Test weight`

Average weights of randomly selected 1000 grains sample of black gram at various moisture content i.e. 10.18, 11.46, 12.22 and 13.86 per cent m. c. (w b) are depicted in Table 1.respectively. It was observed that weight increased with increase in moisture content Fig 3.shows that this increase could be attributed to the moisture absorbed by the grain. Similar results for different granular agricultural materials have been reported by Nimkar and Chattopadhyay (2002) for green gram, Tabatabaeefar (2003) [19] for wheat and Shirkole *et al.* (2011) [18] for soybean.

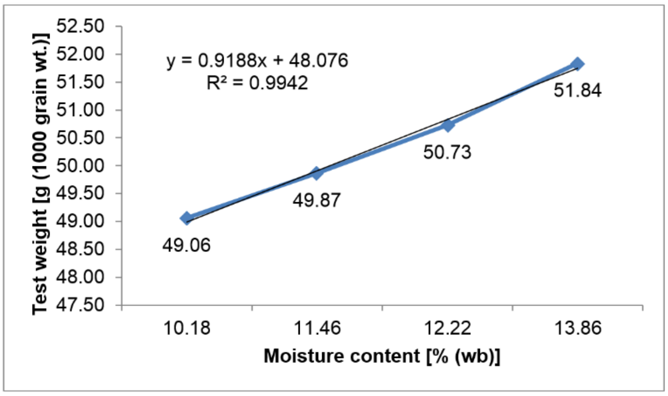

Fig 3: Effect of various moisture contents on test weight of black gram grain

Bulk density

The result of bulk density with moisture content is graphically shown in Fig 4. It was observed that the bulk density decreased linearly with increase in moisture content. 10.18, 11.46, 12.22 and 13.86 per cent m. c. (w b) respectively. The decrease in bulk density for black gram sample with an increase in moisture content indicates that increase in mass owing to moisture gain in grain sample was lower than accompanying volumetric expansion of the bulk. The negative linear relationship of bulk density with moisture content was also observed by various research workers *viz.* Nimkar and Chattopadhyay (2002) for green gram, Kibar (2010) [9] for different rice varieties, Sawant *et al.* (2010) [16] for green gram and Shirkole *et al.* (2011) [18] for soybean.

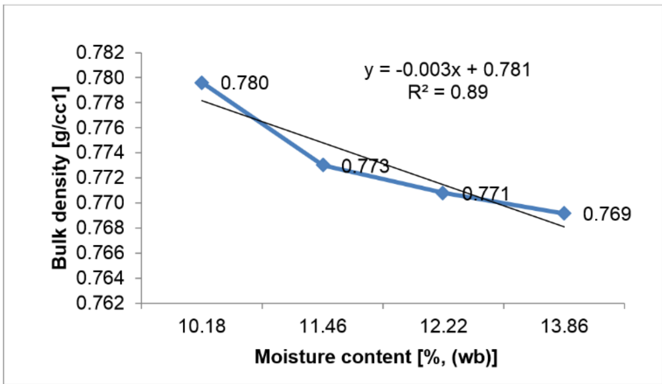

Fig 4: Effect of various moisture contents on bulk density of black gram grain

True density

The variation in true density values with moisture content is graphically shown in Fig 5. at 10.18, 11.46, 12.22 and 13.86 per cent m. c.(w b) respectively. It was observed that the true density decreased linearly with increase in moisture content. It was found that true density values decreased linearly with increase in moisture content. The decrease in true density values in black gram with moisture content might be attributed to relatively high true volume as compared to the corresponding mass of the grain attend due to adsorption of water. Similar result for different granular agro-materials have been reported by Nimkar and Chattopadhyay (2002) for green gram, Tabatabaeefar (2003) [19] for wheat, Bo Wang *et al.* Sawant *et al.* (2010) [16] for green gram and Shirkole *et al.* (2011) [18] for soybean.

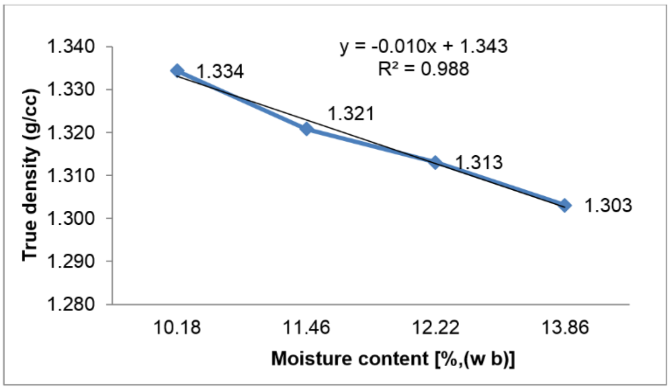

Fig 5: Effect of various moisture contents on true density of black gram grain

Porosity

The porosity of black gram grains varies with moisture content is graphically shown in Fig 6. It was observed that the porosity decreased linearly with increase in moisture content. The decrease of porosity with an increase of moisture content might be due to the difference in shape and size of the different grain. Similar results have been reported by Singh *et al.* (2010) [7] and Shirkole *et al.* (2011) [18] for soybean.

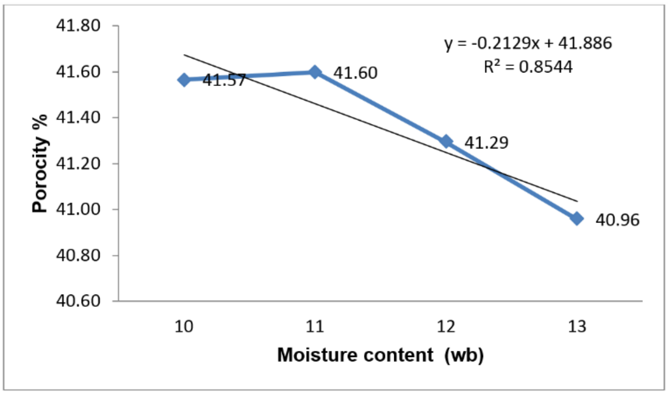

Fig 6: Effect of various moisture contents on porosity of black gram grain

Angle of repose

The variation observed in the angle of repose of black gram grains at different moisture contents is shown in Fig 7. It was observed that angle of repose increased linearly with an increase in moisture content. At higher moisture content within experimental range, grain might tend to stick together resulting in better stability and less flowability which results an increase in the value of the angle of repose. Similar results has been reported by Shirkole *et al.* (2011) [18] for soybean.

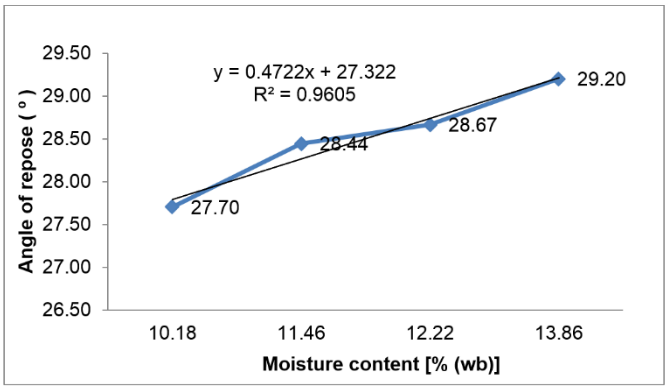

Fig 7: Effect of various moisture contents on angle of repose of black gram grain

Terminal velocity

The result obtained for experimental values of terminal velocity of black gram grain is shown in Fig 8. The difference in terminal velocity of black gram grain may be due to the difference in grain mass, shape and size of the grain Fig. 8 shows a linear relationship between moisture content and terminal velocity. As moisture content increased terminal velocity also increased. Similar results for different granular agro-materials have been reported by Nimkar and Chattopadhyay (2002) for green gram, Tabatabaeefar (2003) [19] for wheat, Bo Wang *et al.* (2007) [5] for fibered flaxseed, Ozturk and Esen (2008) [13] for barley, Davies (2009) [6] for ground nut, Kibar (2010) [9] for different rice varieties, Sawant *et al.* (2010) [16] for green gram and Shirkole *et al.* (2011) [18] for soybean.

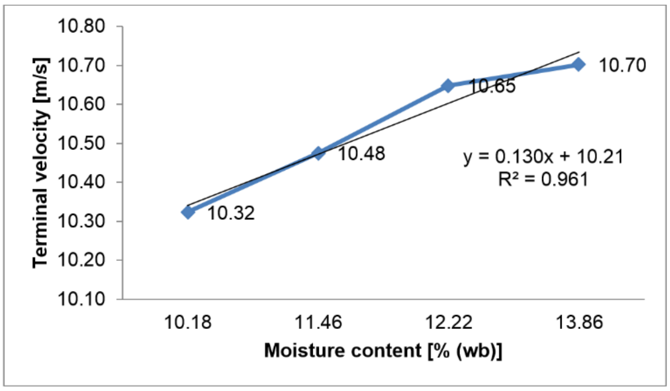

Fig 8: Effect of various moisture contents on terminal velocity of black gram grain

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