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GEOMETRIC AND GRAVIMETRIC CHARACTERISTICS OF BLACK GRAM

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ABSTRACT

Study of physical properties are necessary to determine the appropriate equipment design for processing transportation, separating, storing and drying systems. In this experimental study, some raw material characteristics were determined for the blackgram to get the idea for proper equipment design . The average length, width and thickness were found to be 3.53mm, 2.22mm and 2.29mm at 11.11% moisture content respectively for the dry seeds. The geometric mean diameter, arthimetic mean diameter,equivalent mean diameter, thousand grain weight, sphericity, aspect ratio, surface area and volume were 2.612mm, 2.679mm,4.24mm,40.6g, 74.35%,65.5%, 21.591mm^2 and 9.56mm^3 respectively. True density, bulk density and porosity were 1335.08 kg/m^3,805.091kg/m^3 and 39.697% respectively.

INTRODUCTION

Legume grains are very important in the diets of human being throughout the world. They are the important source of proteins, carbohydrates and minerals .They are the sources of bioactive compounds. Black gram (*Vigna mungo L.*) is an important pulse crop comes from the family of Leguminoseae and belongs to the sub family of Papilionaceae. It is very nutritious and is suggested for diabetics. It has a combination of all nutrients which include 20% to 25% proteins, 40% to 47% starch, ash, fats, carbohydrates, minerals and other essential vitamins. The seed coat colour is ascribed to the presence and quantity of polyphenols such as flavonol glycosides, condensed tannins and anthocyanins. These compounds have antioxidant, antimutagenic and anticarcinogenic activities and also free radical scavenging properties. Black gram is one of the rich sources of vegetable protein and some essential minerals and vitamins for the human body. It has significant lipid lowering action. The knowledge of physical properties such as shape, size, mass, volume, sphericity, surface area, thousand grain weights, bulk density, true density, porosity, conveying, drying, aeration of grains is necessary for the effective and proper design of various separating, handling, storing and drying systems (Sahay and Singh,1994; Tabatabaeefar, 2000). Therefore, in designing the proper equipment for the processing, transportation, separation and storing of the grains, it is necessary to have reliable data about the physical properties of black gram. Designing the seed processing equipment without considering engineering specifications may yield poor results (Davis and El Okene, 2009). The size and shape are important in their electrostatic separation from undesirable materials and in the development of sizing and grading machinery (Mohsenin,1986).The shape of the material is important for an analytical predication of its drying behaviour (Cetin, 2007; Esref and Halil,2007). The study of size is essential for uniformity and packing in standard cartons. Shape and physical dimensions, such as major, intermediate and minor diameters, unit mass, volume and sphericity, are important in screening solids to separate foreign materials and in sorting out various sizes of fruits and vegetables (Stroshine, 2005).

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The smaller the volume of material per unit surface, the better its condition for rapid heat transfer. Volume is important to design fluid velocities for transportation (Tabatabaeefar,2000). Bulk density, true density and porosity can be useful in sizing grain hoppers and storage facilities; they can affect the rate to heat and mass transfer of moisture during aeration and drying processes; useful in containerization, transportation and separation systems (Kachru *et al*., 1994). Grain bed with low porosity will have greater resistance to water vapour escape during the drying process, which may lead to higher power to drive the aeration fans. Grain densities have been of interest in breakage susceptibility and hardness studies. Quality differences in fruits, grains and seeds can be determined by the difference in density. Bulk and true density of agricultural materials play an important role in drying and storage, design of silos and storage bins, separation from undesirable materials, and grading (Tabatabaeefar, 2000). Porosity and surface area affect the resistance to airflow through the bulk material and data on them are necessary in designing the drying process. Porosity is the percentage of air space in particulate solids, affects the resistance to air flow through the bulk solids. Airflow resistance affects the performance of systems designed for force convection drying of bulk solids and aeration systems used to control the temperature of stored bulk solids. Porosity allows gases, such as air and liquids to flow through a mass of particles in aeration, drying, heating and cooling operations. One thousand seed mass is useful in determining the equivalent diameter that can be used in the theoretical estimation of seed volume and in cleaning using aerodynamic forces. It is also important in storage and machinery design. The design of storage and handling systems for grains requires data on bulk and handling properties. Theories used to predict the pressures and loads on storage structures (Lvin, 1970) require bulk density. Also the design of grain hoppers for processing machinery requires data on bulk density. Hence, current study was conducted to investigate some physical properties of black gram.

MATERIALS AND METHODS

Materials

Seeds of black gram were used for all the experimental study. The seeds were obtained from the local market during June 2012 in Tumkur. The sample was selected and cleaned manually. It was ensured that the seeds were free of dirt, broken and immature ones and other foreign materials.

Methods

The initial moisture content of the samples was determined by oven drying at 103 ±2°C for 5 hours (AOAC, 2002). All the physical properties of the seeds were assessed at this moisture (11.11%d.b). The moisture contents (dry basis) of the seed samples were determined by the relationship:

$$\%\ \text{Moisture} = 100\frac{(W_i - W_f)}{W_f} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where W_i = initial weight of the seeds
W_f = final moisture content of the seeds

Geometric Properties

In order to determine dimensions, twenty seeds were randomly selected and for each, size and shape was found to be a hemisphere with the three principal dimensions, namely minor diameter (thickness (T)), intermediate diameter (width(W)) and major diameter (length(L)), were measured using an screw gauge having least count 0.01mm. The geometric mean dimension (D_g) of grains was found using the relationship given by (Mohsenin, 1970; Mohsenin, 1986) as:

$$D_g = \sqrt{LWT} \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

$$D_e = \sqrt{\left(\frac{L(W+T)^2}{4}\right)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

The arithmetic average diameters was calculated using the following relationship (Kiani Deh Kiani *et al.,* 2008; Mohsenin, 1986)

$$D_a = \frac{(L+W+T)}{3} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

The criteria used to describe the shape of the seed are the sphericity and aspect ratio. Thus, the sphericity (Φ) was accordingly computed (Mohsenin, 1970) as:

$$\Phi = \frac{\sqrt[3]{LWT}}{L} * 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

The aspect ratio (R_a) was calculated (Maduako & Faborode, 1990) as:

$$R_a = \frac{W}{L} * 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

The surface area (S_a) was found by analogy with a sphere of the same geometric mean diameter using the expression cited by Arthur (2009) The surface area (S_a) of blackgram as semi sphere was calculated using the relationship (Eqn.7) given by McCabe *et al.,* (1986):

$$S_a = \pi D_g^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots (7)$$

Gravimetric characteristics

Volume of seeds

The unit volume of 100 individual seeds was calculated from values of L, W, and T using the following the equation proposed by Miller (1987)

$$V = \frac{\pi LWT}{6} \quad \ldots\ldots\ldots\ldots\ldots\ldots (8)$$

Thousand Seed Weight (TSW) or Thousand grain mass (M_{1000})

TSW in gram was measured by counting 100 seeds and weighing them in an electronic balance to an accuracy of 0.001g and then multiplied by 10 to give mass of 1000 seeds

True density and Bulk density

The true density (kg/m^3) is defined as the ratio of mass of seeds to the true volume of seeds (Deshpande *et al.,* 1993). The seed volume and its true density was determined using liquid displacement technique (Shepherd, 1986). Toluene was used instead of water so as to prevent the absorption during measurement and also to get the benefit of low surface tension of selected solvent (Sitkei, 1986; Ogut, 1998). The volume of toluene (C_7H_8) displaced was found by immersing a weighed quantity of seeds in the measured toluene (Tavakkoli *et al*., 2006) 50ml of toluene was placed in a 100ml graduated measuring cylinder and 20grams of seeds were immersed in the toluene.The amount of displaced toluene was recorded from the graduated scale of the cylinder. The ratio of weight of seeds to the volume of displaced toluene gave the true density. Seed density was evaluated using the methods suggested by Williams *et al*. (1983). The bulk density ($\frac{kg}{m^3}$) is the ratio of mass of a sample of the seeds to its total volume. It was determined by filling an empty 500ml graduated cylinder with seeds from a height of about 15cm, striking the top level and then weighing the contents (Desphande et al., 1993). The weight of the seeds was obtained by subtracting the weight of the cylinder from the weight of the cylinder with seeds. To achieve the uniformity in bulk density the graduated cylinder was tapped for the seeds to consolidate. The volume occupied was then noted. The process is replicated twice and bulk density for each replication was calculated from the following equation:

$$\rho_b = \frac{W_s}{V_s} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (9)$$

Where ρ_b is the bulk density in kg/m^3

W_s is the weight of the sample in kg;

V_s is the volume occupied by the sample in m^3

Porosity

The porosity (ε) of bulk seed was computed from the values of true density (ρ_t) and bulk density (ρ_b) using the relationship (Eqn.10) (Thompson and Isaacs, 1967; Mohsensin, 1970):

$$\varepsilon = \frac{\rho_t - \rho_b}{\rho_t} * 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots . (10)$$

RESULTS AND DISCUSSION

The physical property of black gram used in this study is indicated in Table 1 and 2. The physical properties such as size, shape and bulk density needed for the design of equipment to handle, transport, process and store and for assessing the product quality (Dunford, 2008; Shkelqim *et al.*, 2008). Moreover, unit operations for the preparation of seeds vary slightly depending on the physical properties (Dunford, 2008). The moisture content of the black gram was found to be 11.11 ± 0.30% dry basis. The moisture content found can help to suggest the stability in storage of black gram, as higher the moisture content more the risk of spoilage of food material.

The average length, width and thickness were found to be 3.53mm, 2.22mm and 2.29 mm respectively. These axial dimensions are important in determining aperture sizes, particularly in separation of materials and other parameters in machine design (Mohsenin, 1970). Length (L) for the blackgram ranged from 2.47 to 3.7mm with the mean value of 3.53mm. Width (W) was distributed in the range of 1.8 to 2.99mm and the seed thickness (T) in the range of 1.71 to 2.9mm respectively (Table 1). The geometric mean diameter ranged from 2.14 mm to 3.16 mm and mean geometric diameter is found to be 2.612mm. The geometric mean of the axial dimensions is useful in the estimation of the projected area of the particle moving in the turbulent region of an air stream. This projected area of the particle is generally indicative of this pattern of behavior in a flowing fluid such as air, as well as the ease of separating extraneous materials from the particle during the cleaning by pneumatic means (Omobuwajo *et al.*, 1999).

Although, Mohsenin (1970) had effectively highlighted the imperativeness of the axial dimensions in machine design, the comparison of the data with existing work on the other seeds can be sufficient in making symmetrical projections towards process equipment adaptation. Other mean of the axial dimensions are the equivalent and arithmetic diameter. Sphericity is an expression of the shape of a solid relative to that of a sphere of the same volume while the aspect ratio related the width to the length of seed which is indicative of its tendency toward being oblong in shape. The sphericity and aspect ratio were 74% and 65.5% **.**It is seen from Table 1 that the sphericity and aspect ratio of the black gram varied from 67 to 87 %, 56 to 81 % respectively. The sphericity value thus suggests that the seeds are of hemispherical shape (Omobuwajo *et al.,* 2000). The fairly high sphericity values show the features favorable to rolling of the grains and therefore have a practical application in handling operations such as conveying and grading. The values of the aspect ratio and sphericity are necessary in the design of hoppers for milling process. However, the surface area ranged from 14 to 31 mm^2 and the corresponding average surface area is 21.591 mm^2 respectively. The surface area is a relevant tool in determining the shape of the seeds. This will actually be an indication of the way the blackgram will behave on oscillating surfaces during processing (Alonge & Adigun, 1999).

Table 1: Geometric Properties of black gram

Properties	Number of observations	Min	Max	Mean	Variance	Std. Deviation
Length (mm)	20	2.47	3.96	3.53	0.125	0.353
Width (mm)	20	1.8	2.99	2.215	0.069	0.263
Thickness (mm)	20	1.7	2.9	2.294	0.076	0.276
Geometric mean diameter(mm)	20	2.137	3.163	2.612	0.058	0.242
Equivalent diameter(mm)	20	3.125	5.626	4.24	0.349	0.591
Arthimetic mean diameter(mm)	20	2.227	3.18	2.679	0.057	0.238
Sphericity (%)	20	67.409	86.66	74.35	42.717	6.536
Surface area (mm^2)	20	14.338	31.417	21.591	16.067	4.008
Aspect Ratio (%)	20	56.782	81.918	65.506	91.12	9.546

Table 2: Gravimetric Properties of black gram

Properties	Number of observations	Min	Max	Mean	Variance	Std. Deviation
Volume (mm^3)	20	5.1	16.578	9.56	7.174	2.678
1000 seed mass (g)	20	39.88	43.11	40.604	0.831	0.912
True density (kg m^{-3})	20	1333.867	1336.2	1335.080	0.868	0.932
Bulk density (kg m^{-3})	20	795.28	816.79	805.091	47.629	6.901
Porosity (%)	20	38.82	40.41	39.697	0.258	0.508

Thousand grain weights of black gram were found to be 40.6g. The weight of food grains is an important parameter to be used in the design of cleaning grains using aerodynamic forces (Oje and Ugbor, 1991). Average volume of seeds is found to be 9.56mm^3. The results of the physical parameters are indicated in Table 2. The true density, bulk density and porosity were 1335kg/m^3,805.1kg/m^3 and 39.7 % respectively. This characteristic can be used to design separation or cleaning process for grains since lighter fractions will float. Porosity may be useful in the separation and transportation of the seeds by hydrodynamic means.

Conclusion

The engineering properties of black grams such as axial dimensions, sphericity, surface area, bulk density, true density, porosity and volume are useful in design and construction of the processing and handling equipments, drying, storing, sorting units and transporting. The average values of physical properties of black gram length, width, thickness, unit mass and volume were determined at a moisture content of 11.11% (dry basis) were 3.53 mm, 2.22 mm, 2.29 mm, 0.0406 g, and 9.56mm^3 respectively. The calculated physical properties like arithmetic mean diameter , geometric mean diameter, equivalent mean diameter, surface area, aspect ratio, sphericity, true density, bulk density and porosity were found to be 2.679mm, 2.612 mm, 4.24mm, 21.591 mm^2,65.606%, 74.35%, 1335kg/m^3,805.1kg/m^3 and 39. 697 % respectively.

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