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ORIGINAL ARTICLE

Physical Properties of Tender Sorghum (*Sorghum bicolor L.*) Grains

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Abstract

The efforts were made to determine the physical properties of tender sorghum (*hurda*) grains of PKV-Ashwini variety. The grain size, sphericity, thousand grains mass, bulk density, true density, porosity, angle of repose, terminal velocity and coefficient of friction were measured. Results of the investigations showed that the grain size increased linearly with increase in moisture content from 68.51 to 73.54 % (w.b.). The average grain size and shericity were 3.46 mm and 0.829 for respectively. The thousand grain mass, bulk density, true density, porosity, angle of repose, terminal velocity and static coefficient of friction were 21.4 g, 617 kg/m^3, 988 kg/m^3, 36.6 %, 33.71, 4.5 m/s and 0.659, respectively. The results found that the increase in moisture content resulted in the increasing of grain width, length, thickness and geometric diameter, porosity, angle of repose where as bulk density and true density were decreased.

Keywords: Size, Sphericity, Bulk density, True density, Porosity, Angles of repose, Terminal velocity, Coefficient of friction.

1. Introduction

Sorghum (*Sorghum bicolor* L.) is an important cereal crop for food and fodder of Indian next to rice, wheat and maize. Largest share of country's production is contributed by Maharashtra and Karnataka states. Due to its ability to grow in dry lands of tropical Africa, India and China it has become the staple diet of these countries also. Sorghum is the main staple food of Maharashtra, Karnataka, and is also an important food of Madhya Pradesh, Tamil Nadu and Andhra Pradesh (Chavan *et al.*, 2013).

Grain sorghum is rich in fiber and apart from having a sufficient quantity of carbohydrates (72 %), proteins (11.6 %) and fat (1.9 %). Starch is the major constituent of the grain. Grain sorghum protein contains albumin globulin (15 %), prolamin (26 %) and glutelin (44 %). Sorghum does not contain gluten and hence the dough does not have stickiness, to roll with the *chapatti* roller. The flour from sorghum is gluten free and is a safe energy source for people allergic to gluten. Minimal amounts of flavan-4-ols and phytic acid are present in white sorghum (Chavan *et al.*, 2013).

Hurda is the name given to tender *Jowar* - the main staple grain of rural Maharashtra, India. In early January, *jowar* grain is juicy and very tender. Just the right time to be eaten roasted. It is generally picked from fields and roasted there and then; this young *jowar* tastes awesome when roasted. The objective of this work is to evaluate various physical properties of the sorghum *hurda* grains of PKV-Ashwini variety.

2. Material and Methods

2.1 Sample Collection and Preparation of Samples

The tender sorghum grain sample of PKV Ashwini was procured from the sorghum research unit of Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola. Selected physical properties of tender sorghum grain, such as Moisture content, Size, Sphericity, Bulk density, True density, Porosity, Thousand grains mass, Angle of repose, terminal velocity and coefficient of friction were determined. The observations of all engineering properties were recorded at initial moisture content of 73.54 % (db.).

Some physical properties of *hurda* grains were studied for proper development of a machine.

2.1.1 Moisture Content

Moisture content of sorghum grain was determined using the procedure detailed by Henderson *et al.* (1997). The grain samples were dried at 1300 C for 18 hours (ASAE, 2003). The weight loss of the samples was recorded and the moisture determined in percentage. This was replicated three times. The moisture content was calculated as:

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$$MC\ wb = \left(\frac{Wi - Wd}{Wi}\right) \times 100$$

Where,

MC wb = Moisture content, wet basis, %.
Wi = Initial weight of sample, kg.
Wd = Dried weight of sample, kg

2.1.2 Size

The size of panicles and grains were specified by length, width and thickness. It was measured by digital vernier calliper (Mityutoyo. least count 0.01 mm). Due to large variation of size of green *hurda* panicles and grains in field, the dimensions of randomly selected ten panicles and fifty grains were measured and average value was calculated.

2.1.3 Sphericity

The sphericity is a measure of shape character compared to a sphere. 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 largest intercept of the ellipsoid. The degree of sphericity was calculated by using the equation 3.1(Mohsenin, 1986).

$$\text{Sphericity} = \frac{(a \times b \times c)^{\left(\frac{1}{3}\right)}}{a}$$

Where,

a = longest intercept, mm
b = Longest intercepts normal to a, mm
c = Longest intercept normal to a and b, mm

2.1.4 Thousand Grain Mass

One thousand randomly selected grains were collected and weighed on electronic balance (Sansui SSP SERIES, least count 1 g). This magnitude was termed as the thousand grain weight specific to the grain. The procedure described in ISI: 4333 (Part IV)-1968 was adopted. Average of three replications have been considered and reported as thousand mass.

2.1.5 Bulk Density

Bulk density of a sample is the ratio of its mass to bulk volume. To measure the bulk density of the grain, the method given in IS: 4333 (Part III) - 1967 was used which involves filling up standard kettle of 500 ml with seed from a height of 150 mm and then weighing the contents. Average of three replications was reported as the bulk density *hurda* grains (Mohsenin, 1986).

2.1.6 True Density

The ratio of mass of sample to the true volume is termed as true density of the sample. It was determined with toluene displacement method. Grain sample (about 10 g) was submerged in toluene in measuring cylinder having an accuracy of 0.1 ml. The increase in liquid volume due to sample was noted as true volume of sample. Average of three replications was considered as a true density value of *hurda* grains (Mohsenin, 1986).

2.1.7 Porosity

It is the percentage of volume of voids in the test sample at given moisture content. It was calculated as the ratio of the difference in the true and bulk density to the true density (equation 3.2). Average of three replications was considered as a porosity of *hurda* grains (Mohsenin, 1986).

$$\text{Porosity, \%} = \frac{\rho t - \rho b}{\rho t} \times 100 \qquad \dots (3.2)$$

Where,

ρ_t = True density
ρ_b = Bulk density

2.1.8 Angle of Repose

Angle of repose is defined as when a granular material is allowed to flow freely from a point into a pile, the angle, which the side of pile makes with the horizontal plane, is called as angle of repose. For measuring the angle of repose a GI sheet box of 210×210×210 mm size, having funnel with 120 mm circular disc fitted inside discharge gate below the box was fabricated and use for the experimentation. The box filled with grain will placed on the floor and discharge gate then quickly will removed allowing the grain to slide down and assume their natural slope. The angle of repose calculated by using formula:

$$Ø = \tan^{-1} 2H/D \qquad \dots (3.3)$$

Where,

Ø = Angle of repose, degree
H = Height of pile, mm
D = Diameter of disc, mm

2.1.9 Terminal Velocity

The velocity at which the net gravitational accelerating force equals the resisting upward drag force is term as terminal velocity. The terminal velocity of tender sorghum grain sample at different moisture contents were measured using air column. For each test of sample (about 10 g) was dropped into the air stream from the top of the air column, up to which air column blown to suspend the material in the air stream. Air velocity near the location of the grain suspension was measured by an electronic anemometer having a least count of 0.1 m/s.

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Table 1: Principle dimensions, grain size and sphericity values of different tender sorghum varieties

Variety	Moisture content, % (w.b.)	Major axis, (mm)	Medium Axis, (mm)	Minor Axis, (mm)	Grain size, (mm)	Spericity
PKV-Aswini	68.51	4.45(±0.35)	4.08(±0.37)	2.97(±0.38)	3.40	0.829
	71.70	4.70(±0.52)	4.10(±0.36)	3.02(±0.37)	3.46	0.827
	73.54	4.60(±0.36)	4.35(±0.53)	3.38(±0.65)	3.53	0.833

Table 2: Thousand grain mass, bulk density, true density, porosity, angle of repose, terminal velocity and static coefficient of friction values of different tender sorghum varieties

Variety	Moisture Content, % (w.b.)	Thousand Grain mass, (G)	Bulk Density, (Kg/m^3)	True Density (Kg/m^3)	Porosity (%)	Angle of repose, (degree)	Terminal velocity (m/s)	Static Coefficient of Friction (plywood)
PKV-ashwini	68.51	21.2	636	996	35.79	33.16	4.30	0.632
	71.70	21.4	612	986	36.23	33.76	4.52	0.660
	73.54	21.8	604	982	37.84	34.23	4.68	0.686

2.1.10 Static Coefficient of Friction

The ratio between the force of friction and the force normal to the surface of contact is term as static coefficient of friction. Coefficient of friction is given by the tangent of the angle of the inclined surface upon which the friction tangential to the surface and to the component of the weight normal to the surface is acting.

3. Results and Discussion

Physical parameters of tender sorghum grain such as moisture content, size, sphericity, bulk density, true density, porosity, and thousand grains mass, angle of repose, terminal velocity and coefficient of friction were investigated and the results are tabulated below Table 1 and 2.

The average values obtained for the size were 3.40 mm, 3.46 mm and 3.53 mm, respectively at moisture content ranging from 68.51 to 73.54 % wb. respectively. The grain size increased linearly with higher moisture content. The dimensions as a function of grain moisture content, *M* are mathematically represented as following equation:

$$D_m = 1.68 + 2.51 \times 10^{-2} M$$
$$R^2 = 0.96 \quad \ldots (1)$$

The variations of the sphericity with moisture content were observed. The sphericity ranged from 0.829-0.833 at moisture content 68.51 to 73.54 % wb respectively. Bhosale (2016) reported similar trend for tender jawar.

The thousand grain mass increased linearly with higher moisture content. The thousand grain mass increased from 21.2 to 21.8 g at moisture content ranging from 68.51 to 73.54 % wb. This trend was also observed in many works. The variation can be expressed mathematically, as shown in (2).

$$W_g = 13.41 + 0.11 M$$
$$R^2 = 0.88 \quad \ldots (2)$$

The bulk density decreased with increase in moisture content. The bulk density values were found to be 636 kg/m^3 to 604 kg/m^3 at moisture content 68.51 to 73.54 % wb respectively. The variation can be expressed mathematically, as shown in (3).

$$\rho_b = 1679 - 6.49 M$$
$$R^2 = 0.98 \quad \ldots (3)$$

The true density decreased with increase in moisture content. The true density values were found to be 996 kg/m^3 to 982 kg/m^3 at moisture content 68.51 to 73.54 % wb respectively. The variation can be expressed mathematically, as shown in (4).

$$\rho_t = 1189.1 - 2.822 M$$
$$R^2 = 0.99 \quad \ldots (4)$$

The bulk porosity values were calculated from the experimentally determined bulk density and true density values of tender sorghum and are given in Table 2. Porosity values of these varieties were found to increase linearly with increase in moisture content. The result indicated that the increase in porosity value of PKV-Ashwini were observed as 35.79, 36.29 and

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37.84 corresponding increase in moisture content from 68.51, 71.70 and 73.54 percent (w.b.) respectively. The result obtained from this study is in agreement with those of Bhosale (2016) who obtained bulk density, true density and bulk porosity respectively.

$$\in = 9.710 + 0.3777 M$$
$$R^2 = 0.79 \quad \ldots (5)$$

The angle of repose of whole grain was found linearly with increase in moisture content. The angle of repose of tender sorghum was found to be 33.16, 33.76 and 34.23 corresponding increase in moisture content from 68.51, 71.70 and 73.54 percent (w.b.) respectively. Furthermore, the correlation between this angle of repose and moisture content was found to be linear as confirmed by following equations:

$$\theta = 18.75 + 0.21 M$$
$$R^2 = 0.99 \quad \ldots (6)$$

The increase in terminal velocity was found with increasing moisture content. The result indicated that the terminal velocity increased as 4.30, 4.52 and 4.68 m/s with their corresponding increase in moisture content from 58.43, 61.33 percent (w.b.) respectively. The variation can be expressed mathematically, as shown in (7).

$$V_t = -0.8307 + 0.0748 M$$
$$R^2 = 1.00 \quad \ldots (7)$$

The coefficient of friction that occurs due to the movement of whole grains over plywood surfaces was also estimated. The coefficient of static friction was recorded 0.632, 0.660 and 0.686 for plywood with their corresponding increase in moisture content from 58.43, 61.33 percent (w.b.) respectively.

4. Conclusion

From the above investigation, selected physical properties of *PKV Ashwini* such as Moisture content, Size, Sphericity, Bulk density, True density, Porosity, Thousand grains mass, Angle of repose, terminal velocity and coefficient of friction were determined. All the properties were assessed at an average moisture content of 71.25±1.1 per cent (wb) for the fresh tender sorghum. The principal dimensions varied with increase in moisture content. With increasing moisture content, width, thickness and grain size of the tender sorghum grains increase linearly. Shericity, 1000-grain mass, porosity and static coefficient of friction increased with increase in moisture content, while decrease in bulk and true density was found with higher moisture content. Terminal velocity increased linearly with increase in grain moisture content.

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