



P-ISSN: 2349-8528

E-ISSN: 2321-4902

www.chemijournal.com

IJCS 2020; 8(6): 139-142

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Received: 18-10-2020

Accepted: 26-12-2020

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Physical properties of *Hurda* (Tender Sorghum)

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DOI: <https://doi.org/10.22271/chemi.2021.v9.i1b.11221>

Abstract

Research were conducted to evaluate some moisture dependent engineering properties of *hurda* (tender sorghum) PKV *Ahwini* in the moisture range of 62.28 to 70.13 % (d. b.). It was aimed at investigating engineering properties of *hurda* (tender sorghum) viz., moisture content (db), bulk density, porosity, true density, sphericity, geometric mean diameter, angle of repose, coefficient of friction and thousand kernel weight.

Results of the investigations showed that length, breadth and thickness were increased linearly with increase in moisture content. The grain size increased linearly with increase in moisture content from 62.28 to 70.13 % (w.b.). The average values obtained for the size were 3.55 mm, 3.78 mm and 4.03 mm, The sphericity ranged from 0.838-0.869 at moisture content 62.28 % to 70.13 % (w.b.) respectively. Thousand grain mass was increased from 20.41 to 21.14 g with corresponding increase in moisture content. Bulk density was decreased from 662 kg/m³ to 610 kg/m³. Whereas, true density was decreased from 997 kg/m³ to 984 kg/m³.

Keywords: *Hurda*, tender sorghum, physical properties, frictional properties

Introduction

Hurda is the name given to tender sorghum. *Hurda* is one among the special sorghum and it is ready to eat snacks. In early January, sorghum grain is juicy and very tender. Just the right time to be eaten roasted. Bunches of *hurda* with stems that work as a grip are pushed in the hot pit. In about five minutes the tender grains are nicely roasted. The pit keepers, i.e. *hurda* makers, have mastered the art of holding the roasted *hurda*, burning hot, in their bare palms. Vigorous rubbing, using both the palms, separates the roasted *hurda* from the chaff.

Hurda is commonly eaten with the hull, which retains the majority of the nutrients and very high in fiber and iron, with a fairly high protein level and also a good source of phosphorus and thiamine. *Hurda* is rich in antioxidants and all sorghum varieties are gluten-free, an attractive alternative for wheat allergy sufferers. The tender jowar can be very good fast food (Meti *et al.* 2014) [10]. Sorghum in general is rich source of fiber and B-complex vitamins (Gopalan *et al.*, 2000 and Patil *et al.*, 2010) [4, 14].

There is a need for popularize sorghum food as sorghum with its high minerals and fiber content and with low or slow starch digestibility makes an ideal food for diabetic and obese population in the urban as well as rural society. Nowadays agro-tourism business is increasing in the rural area and in that contest supplying sorghum *hurda* as a niche product get the more profit to the farmer/producer (Chavan *et al.*, 2013) [2].

Basic information on engineering properties is of great importance and help engineers towards efficient process and equipment development. These properties are useful in the design of processes, machines, structures and controls. These properties are used in analyzing and determining the efficiency of the machine and operation or process as well as determining quality or studying the behavior of the product during agricultural processing unit operations (Surpam, 2019) [17]. Also aerodynamic properties of agricultural products are important and required for design of air conveying systems and the separation equipment (Sahay and Singh, 1994) [16].

The physical properties such as size, shape, surface area, volume, density, porosity, color and appearance are important in designing a particular equipment or determining the behaviour of the product for its handling. It is quite important to have an in depth knowledge of the physical and mechanical properties of oil bean seed which is considered an essential engineering data

needed in the design of machine, storage structures, processing and quality control. Design of these equipment without putting these physical and mechanical properties into consideration may yield poor results (Oluka *et al.*, 2010) [13].

While, extraction of *hurda* (tender sorghum), the physical properties of *hurda* (tender sorghum) at different moisture content will be varied and needs to be determined its properties for design and development of *hurda* (tender sorghum) extraction machine. Hence, keeping the above factors in view, a study has been undertaken to found out physical properties of *hurda* (tender sorghum) such as size, shape, bulk density, moisture content, sphericity, arithmetic and geometric mean diameter.

Materials and Methods

Sample collection and preparation of samples

The *hurda* (tender sorghum) sample of PKV *Ashwini* was procured from the sorghum research unit of Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola. Selected physical properties of *hurda* (tender sorghum), such as moisture content, geometric mean diameter, 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 different moisture content of 62.28% to 70.13% (db.). Some physical properties of *hurda* (tender sorghum) were studied for proper development of a machine.

Moisture Content

Moisture content of sorghum grain was determined using the procedure detailed by Henderson *et al.* (1997) [5]. The grain samples were dried at 130°C for 18 hours (ASAE, 2003) [1]. 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:

$$M.C (w.b.) = \frac{(W_1 - W_2)}{W_1} \times 100$$

Where

M.C = Moisture content of sample, per cent
 W_1 = Initial mass of samples before drying, g
 W_2 = Final mass of samples after drying, g

Length, breadth, thickness (L, B, and T)

For determination of L, B and T one thousand grains were randomly picked from each sample. The length (L), breadth (B) and thickness (T) were measured by using digital Vernier calliper (± 0.01 mm).

Grain size

The average diameter of the grain was calculated by using arithmetic mean and geometric mean of the three axial dimensions. The mean values of the linear dimensions were then determined and the arithmetic mean (D_{AM}) and geometric mean diameter (D_{GM}) calculated using below Equations (Mohsenin, 1986) [11].

$$AMD = \frac{L+B+T}{3}$$

$$D_{GM} = (LBT)^{1/3}$$

Where

L = longest intercept (Length),
 B = longest intercept normal to L (Width) and
 T = longest intercept normal to L and B (Thickness).

Sphericity (Φ)

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 formula (Mohsenin, 1986) [11].

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

Where,

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

Bulk density (ρ_b)

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 grain from a height of 150 mm and then weighing the contents. Average of three replications was reported as the bulk density sorghum grain (*hurda*) grains (Mohsenin, 1986) [11].

$$\text{Bulk density (kg/m}^3\text{)} = \frac{\text{Weight of sample in container}}{\text{Volume of sample}}$$

True density (ρ_t)

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 were considered as a true density value of *hurda* grains (Mohsenin, 1986) [11].

$$\text{True density (kg/m}^3\text{)} = \frac{\text{Weight of sample}}{\text{True volume of sample}}$$

Porosity (ϵ)

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 3.8). Average of three replications was considered as a porosity of sorghum grain (*hurda*) (Mohsenin, 1986) [11].

$$\text{Porosity \%} = \frac{\rho_t - \rho_b}{\rho_t} \times 100$$

Where,

ρ_t = True density, Kg/m³
 ρ_b = Bulk density, Kg/m³

Angle of repose (Θ)

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

120mm circular disc fitted inside discharge gate below the box was fabricated and used for the experimentation. The box filled with grain was placed on the floor and discharge gate was then quickly removed allowing the grain to slide down and assume their natural slope. The angle of repose calculated as given below (Mohsenin, 1986) ^[11].

$$\theta = \tan^{-1} 2H/D$$

Where,

θ = Angle of repose, degree

H = Height of pile, mm

D = Diameter of disc, mm

Terminal velocity

Terminal velocity was measured by using an air column system. For each experiment, a sample was dropped into the air stream from the top of the air column. The air was blown up to suspend the material in the air stream. The air velocity near the location of the grain suspension was measured by anemometer having a least count of 0.01 m/s. (Gharibzadeh *et al.*, 2010) ^[3].

Thousand grain weight (M1000)

One thousand randomly selected sound grains of test sample at various moisture levels were collected and weighed on electronic top pan balance (Contech, India) having a least count of 0.01 g. This magnitude was termed as the thousand grain weight specific to the grain. The procedure described in IS: 4333 (Part IV) -1968 was adopted. Average of ten replications have been considered and reported as thousand grains weight of the sample.

Static coefficient of friction (μ_{sta})

The coefficient of friction between grain and wall is an important parameter in the prediction of grain pressure on walls. The coefficient of friction of the sorghum grain on surfaces such stainless steel sheet were determined. The static angle of friction was recorded when the grain just began to slide on the test surface (Mohsenin, 1986) ^[11].

Results and Discussion

The influence of moisture levels on physical parameters of *hurda* (tender sorghum) such as at different moisture levels, 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 4.2 and Table 4.3.

Length breadth and thickness (L, B and T)

The axial dimensions of the sorghum grain (*hurda*) were linearly increased in the simulated moisture content range of 62.28 to 70.13 % (d.b.). The length of *hurda* (tender sorghum) increased from 4.24 to 4.64 mm, breadth increased from 3.91 to 4.36 mm and thickness increased from 2.82 to 3.38 mm with the corresponding increase in moisture content from 62.28 % to 70.13 % (d.b.). The increase in axial dimensions of sorghum grain with increase in moisture content is due to absorption of water by grains. Kenghe *et al.*, (2015) ^[8] for sorghum; Masane *et al.* (2016) ^[9] for tender *jawar* Surpam *et al.*, (2019) ^[17] also reported the same trend for sorghum.

Grain size (Dm)

The grain size increased linearly with higher moisture content. The grain size were ranged from 3.55mm, 3.78mm

and 4.03 mm with the corresponding increase in moisture content from 62.28 % to 70.13 % (d.b.). The result obtained from this study are in agreement with those of Masane *et al.* (2016) ^[9].

Sphericity (Φ)

The values of sphericity were calculated individually by using the data on geometric mean diameter and the major axis of the *hurda* (tender sorghum). The variation of the sphericity with moisture content were recorded and which indicates that sphericity was linearly decreased with decreasing trend of moisture content. The sphericity ranged from 0.838-0.869 at moisture content 62.28 % to 70.13 % (w.b.) respectively. Similar findings for sphericity determination for various grains has been reported by Kenghe *et al.*, 2018 and Masane *et al.* (2016) ^[9].

Thousand grain weight (M₁₀₀₀)

The thousand grain mass increased linearly with higher moisture content. The thousand grain mass increased from 20.41 to 21.14 g at moisture content ranging from 62.28 % to 70.13 % (w.b.). The increase in thousand grain weight was due to moisture absorbed by the grains. The increased values of thousand grain weight are in agreement with Kenghe *et al.*, 2018 for sorghum and Masane *et al.* (2016) ^[9] for tender sorghum.

Bulk density (ρ_b)

The bulk density decreased with increase in moisture content. The bulk density values were found to be 662 kg/m³ to 610 kg/m³ at moisture content 62.28 % to 70.13 % (w.b.) respectively. The bulk density was decreased linearly with increase in moisture content. The result showing decreased in bulk density with increase in moisture content were in conformity with the earlier findings for tender sorghum (Masane *et al.* 2016) ^[9].

True density(ρ_t)

True density was linearly decreased with increase in moisture content. The true density values were found to be 997 kg/m³ to 984 kg/m³ at moisture content 62.28 % to 70.13 % (w.b.) respectively.

Bulk porosity (ϵ)

The bulk porosity values were calculated from the experimentally determined bulk density and true density values of *hurda* (tender sorghum). Porosity values of these varieties were found to increase linearly with increase in moisture content. The result indicated that the increase in porosity value were observed as 33.57, 35.69 and 38.05 corresponding increase in moisture content from 62.28, 65.78 and 70.13 percent (w.b.) respectively. The result obtained from this study is in agreement with bulk density, true density and bulk porosity respectively (Masane *et al.*, 2016) ^[9].

Angle of repose (θ)

The angle of repose linearly increases with increase in moisture content 62.28 % to 70.13 % (w.b.) respectively. The angle of repose of *hurda* (tender sorghum) was found to be 33.14, 33.54 and 33.77 corresponding increase in moisture content from 62.28, 65.78 and 70.13 percent (w.b.) respectively. The increasing trend of angle of repose with moisture content occur because surface layer of moisture surrounding particle hold the aggregate of grain together by surface tension (Pradhan *et al.*, 2008) ^[15]. The increased

values of angle of repose are in agreement with Mwithiga and Mark (2005) ^[12] for sorghum; Kenghe *et al.*, (2018) for sorghum.

Terminal velocity

The increase in terminal velocity was found with increasing moisture content. The result indicated that the terminal velocity increased as 4.35, 4.41 and 4.54 m/s with their corresponding increase in moisture content from 62.28, 65.78 and 70.13 percent (w.b.) respectively.

Coefficient of friction

The coefficient of friction that occurs due to the movement of whole grains over stainless steel surfaces was also estimated. The coefficient of static friction was recorded 0.622, 0.638 and 0.657 for stainless steel with their corresponding increase in moisture content from 62.28, 65.78 and 70.13 percent (w.b.) respectively.

Conclusion

Based on the results discussed following conclusions could be drawn:

1. Length, breadth and thickness were found to be increased from 4.24 to 4.64 mm, 3.91 to 4.36 and 2.82 to 3.38 mm.
2. The grain size was found to be increased from 3.55 to 4.03 mm.
3. Sphericity was decreased from 0.838 to 0.869.
4. Thousand grain weight was increased from 20.41 to 21.14 g
5. Bulk density was decreased from 662 to 610 Kg/m³
6. True density was decreased from 997 to 984 Kg/m³
7. Porosity was increased from 33.57 to 38.05%.
8. Angle of repose was increased from 33.14 to 33.77 degree.
9. Terminal velocity was increased from 4.34 to 4.54 m/s.
10. Coefficient of friction was increased from 0.622 to 0.657.

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