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Engineering Properties of Sorghum Kernel's at different Moisture content

Mahendra Daheriya[1*], Mohan Singh[2], D.K. Verma[3], Er. K.C. Mahajan[3] and Swati Singh Maravi[4]
[1]Ph.D. Scholar (Post Harvest Process and Food Engineering),
College of Agricultural Engineering, Jabalpur (Madhya Pradesh), India.
[2]Professor, Department of Post-harvest Process and Food Engineering,
College of Agricultural Engineering, JNKVV, Jabalpur (Madhya Pradesh), India.
[3]Assistant professor, Department of Post Harvest Process and Food Engineering),
College of Agricultural Engineering, Jabalpur (Madhya Pradesh), India.
[4]Masters Student (Post Harvest Process and Food Engineering),
College of Agricultural Engineering, Jabalpur (Madhya Pradesh), India.

(Corresponding author: Mahendra Daheriya)*
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ABSTRACT: The fifth-most important cereal in the world is sorghum, which is widely cultivated for human consumption and for use in animal feed. Physical characteristics like size, shape, surface area, volume, density, porosity, colour, and appearance are crucial when designing a specific piece of machinery or figuring out how a product will behave during handling. Standard methods were used to determine the physical properties of sorghum grains. In this study, the average value of sorghum grain dimension was determined at various moisture contents. At 12%, 14%, 16%, 18%, and 20% moisture content, the 1000 grain weight was found to be 39.52 g (±1 g), 47.92 g (±1 g), 52.76 g (±1 g), 61.06 g (±1 g), and 67.26 g (±1 g), respectively. The length (4.30), width (3.87) and thickness (2.74) of the soaked sorghum were linearly increased according to moisture content. The equivalent diameter (4.44), square mean diameter (6.17), arithmetic mean diameter (3.62), geometric mean diameter (3.57), degree of sphericity (0.84), aspect ratio (0.89), and shape factor (4.22) of soaked sorghum all increased with moisture content. The variation of bulk density and true density of sorghum grain with moisture level. The bulk density of sorghum grain decreased linearly from 824 to 801 kg/mm^3. The true density of sorghum grain decreased linearly from 1560 to 1370 kg/mm^3, respectively. Basic information on these engineering properties is of great importance and help engineers towards efficient process and equipment development.

Keywords: Moisture content, Bulk density, true density, porosity, Degree of sphericity.

INTRODUCTION

The fifth-most important cereal in the world, sorghum is a popular food and feed grain. Approximately 90% of the sorghum-growing area on earth is found in developing nations. India is second in production to the United States and covers the most land in the world (32.3%) that is planted with sorghum. India produced 4.77 million metric tonnes of sorghum grain in 2019–20 from an area of 5.10 million hectares (Anonymous 2011). (https://www.fao.org/faostat/en/#data/QCL)

Cereals play an important role in the human diet. Cereals belong to the *Poaceae* family, which includes wheat, rice, barley, oats, rye, and sorghum. Agriculture is one of the strongholds of the Indian economy and accounts for 18.5 percent of the country's gross domestic product. Sorghum is a coarse grain and now it is being accepted as a staple diet and its demand is increasing year by year. In India, sorghum is the third most important cereal crop after rice and wheat in terms of area currently, 49% of sorghum output is used as poultry feed, 25% as food, 13% in starch and other industries, 12% as animal feed, and 1% as seed (Anonymous, 2011).

The vast majority of people in Africa and Central India depend on it for their dietary and micronutrient needs. It is an important food crop for many people in Africa and Asia. After rice and wheat, it ranks third in terms of area and production. The Great Plains of North America, Sub-Saharan Africa, North Eastern China, India, Argentina, Nigeria, Egypt, and Mexico are the major sorghum growing areas. It was India's second largest grain crop until the green revolution, and it now ranks third in terms of acreage and production among food grains. In many Indian states, it is a staple food grain. Recent crop trends in India show that sorghum cropped area is declining dramatically. However, sorghum remains the main staple food for India's poor and marginal farmers. The crop has enormous potential and has been identified as one of the climate resilient crops capable of quickly adapting to changing climatic conditions (Surpam *et al*., 2019).

Sorghum grain's nutrient profile shows that it is a good source of protein, vitamins, minerals, and trace elements in addition to being a good source of energy (Gopalan *et al.,* 2007). 11.9% of the grain's weight is made up of moisture, 10.4% of it is protein, and 1.9% is fat. Grain sorghum has a 1.6% mineral and fibre content. About 349 kcal and 72.6% of its calories come from carbohydrates, making it a good source of energy. Starch is the grain's main source of carbohydrates. Simple sugars, cellulose, and hemicellulose are among the other carbohydrates found. Dietary fibre makes up 14.3% of sorghum's content. For every 100 g of edible sorghum, there are 25 mg of calcium, 222 mg of phosphorus, and 4.1 mg of iron (Hosmani and Chittapur 1997).

Moisture is one of the most important factors in the preservation of sorghum grains during storage because of its connection to the biological elements that cause postharvest damage, which has an impact on the grain's economic and nutritional value (Gely *et al.,* 2017). In order to determine the design and operating parameters for the post-harvest processes, it is critical to assess the impact of moisture content on the physical characteristics of the grain. Therefore, the objective of this work is to examine how physical characteristics of technological interest for the post-harvest grain sorghum stages depend on moisture content. According to the results of the experiments, moisture has a significant impact on the characteristics of thousand seed weight, geometric mean diameter, sphericity, true density, bulk density, and porosity.

MATERIALS AND METHOD

India has the largest area under cereals. Sorghum is commonly grown coarse cereals in different parts of India. These cereal also used to develop value-added products for many decades, and they have a large market for consumption. (Local variety) procured from the local market of the Jabalpur were selected for the present investigation.

Measurement of physical properties of sorghum. The physical properties of sorghum is important to design the processing machineries and equipment. The physical properties such as length, width and thickness of soaked sorghum was considered for designing the drying grading and storage machine

Moisture content. The moisture content of the soaked sorghum was determined using a hot air oven at 130°C for two hours. Moisture was added or reduced in the grain based on the results to test the physical properties of the grain at various moisture levels. In a 100 ml beaker, 10 g of sample was immersed in distilled water (1:3). After two hours, 10 g of soaked sorghum were removed from the 100 ml beaker. Tissue paper was used to remove surface water from the grain. The moisture content of soaked sorghum was determined in three replicates using the hot air oven method per ASAE Standard S352.2 for sorghum.

$$\text{Moisture content}(\%) = \frac{\text{Initial weight (g)-final weight (g)}}{\text{Initial weight (g)}} \times 100 \quad (1)$$

Thousand grain weight. 1 kg of sorghum grains were divided into 10 equal portions, and 1000 grains were randomly selected from each portion and weighed with a digital electronic balance with an accuracy of 0.001g. The mean value of thousand grains weight of sorghum was determined using three replications (Khedekar, 2013).

Determination of length (L), width (W) and thickness (T) of soaked grains. Sorghum grains were measured for length (l), breadth (b), and thickness (t). The dimensions of grain kernels selected for the present investigation were measured using a digital Vernier Caliper with 0.001 mm accuracy in three orientations. A total of 20 randomly selected sorghum kernels were collected (Pordesimo *et al*., 1997).

The following equations were used to calculate the arithmetic mean diameter (AMD), geometric mean diameter (GMD), square mean diameter (SMD), equivalent diameter (EQD), degree of sphericity (Sp), aspect ratio (AR), shape factor (λ) and unit volume of soaked sorghum grains.

$$\text{AMD} = \frac{L+W+T}{3} \quad (2)$$

$$\text{GMD} = \sqrt[3]{LWT} \quad (3)$$

$$\text{SMD} = \sqrt{LW+WT+TL} \quad (4)$$

$$\text{EQD} = \frac{AMD+GMD+SMD}{3} \quad (5)$$

$$Sp = \frac{GMD}{L} \quad \text{(Mohsenin, 1986)} \quad (6)$$

$$AR = \frac{W}{L} \quad (7)$$

Where,
L = length (mm)
W = width (mm)
T = thickness (mm)
AMD = arithmetic mean diameter
GMD = geometric mean diameter
SMD = square mean diameter
EQD = equivalent diameter
S_p = degree of sphericity
AR = aspect ratio

Major dimensions were used to calculate the surface area (S) of single grain as details below

$$S = \frac{\pi \times GMD \times L^2}{2L - GMD} \quad (8)$$

$$V_t = \frac{\pi \times GMD^2 \times L^2}{6(2L - GMD)} \quad (9)$$

Where,
V_t = unit volume
L = length (mm)
GMD = geometric mean diameter

Based on grain surface area and unit volume, the shape factor (λ) was calculated as (Mc. Cabe and Smith 1984)

$$\lambda = \frac{a}{b} \quad (10)$$

$$a = \frac{V_t}{W^4} \quad (11)$$

$$b = \frac{s}{6W^2} \quad (12)$$

Where,

V_t = unit volume (mm³)

W = width (mm)

S = Surface area (mm²)

Equivalent diameter and sphericity. Equivalent diameter (D_p) and sphericity (∅) of sorghum kernels were determined using the equations (Mohsenin, 1970), as given below.

$$D_p = (lbt)^{1/3} \quad (13)$$

$$\emptyset = \frac{(lbt)^{1/3}}{l} \quad (14)$$

Where,

l = Length of the grain, mm

b = Width of the grain, mm

t = Thickness of the grain, mm

Bulk density, True density and Porosity measurement. The bulk density was determined by filling a 1000ml container with soaked sorghum grains to a height of about 150 mm, striking the top level, and then weighing the content. The ratio of weight of the sample and volume occupied by it is expressed as bulk density, g/ml (Konak *et al*., 2002).

$$\text{Bulk density} = \frac{\text{Weight of sample}}{\text{Volume of sample}} \quad (15)$$

The true density of the soaked sorghum grains was determined by the toluene displacement method. Soaked sorghum grains (about 5g) were submerged in toluene in a measuring cylinder. The increase in volume due to soaked sorghum grains was noted as the true volume of soaked sorghum grains, which was then used to determine the true density of the soaked sorghum grains (Wandkar *et al.,* 2013).

$$\text{True density} = \frac{\text{Mass of grain}}{\text{Displaced volume}} \quad (16)$$

Porosity (έ) is the ratio of volume of internal pores to its bulk volume. It was calculated as the ratio of the difference between the true density and bulk density to the true density and expressed by Mohsenin (1986) as:-

$$έ = \frac{\rho_t - \rho_b}{\rho_t} \quad (17)$$

Where, ρ_t= True density and

ρ_b = Bulk density

RESULT AND DISCUSSION

Physical properties of sorghum. The design of machinery and equipment for grading, sorting, separating, processing, and packaging such machinery and equipment depends on the quality of sorghum. Without it, the outcome might not be as good. The primary physical features of biological materials are shape, size, mass, bulk density, porosity, and static coefficient of friction against various surfaces (Mohsenin, 1986).

Moisture Content. The moisture content was found to be used with the standard AOAC (1984) oven drying method. We took different moisture content like 12%, 14%, 16%, 18%, and 20% to find out the different physical properties of sorghum grains.

Thousand Grains of Weight. The weight of 1000 grains increases as the moisture content of the sorghum grains increases. The weight of the grains varies according to their moisture content. We found that the moisture content of the sorghum grains was 12, 14, 16, 18, and 20 percent, and that the weight of the 1000 grains was 39.52 g (±1 g), 47.92 g (±1 g), 52.76 g (±1 g), 61.06 g (±1 g), and 67.26 g (±1 g), respectively.

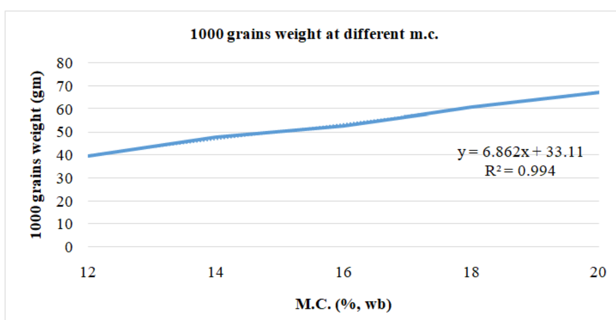

Fig. 1. Effect of moisture content on 1000 grains weight.

Determination of length (L), width (W) and thickness (T) of soaked sorghum grains. It is observed that the average values of three principal dimensions of raw sorghum, namely length, width, and thickness determined in this study at different moisture content are presented. Each dimension appeared to be linearly dependent on the moisture content. A very high correlation was observed between the three principal dimensions: length, width, and thickness within the moisture range of 12 to 20 for sorghum grain. The average value of sorghum grains dimension was determined in this study at 12%, 14%, 16%, 18%, and 20% moisture content.The average length (4.30), width (3.87) and thickness (2.74) of the soaked sorghum were linearly increased according to moisture content.

Equivalent diameter and sphericity. Arithmetic mean diameter (3.62), Geometric mean diameter (3.57), Squire mean diameter (6.17), Equivalent diameter

(4.44), Degree of sphericity (0.84), Aspect ratio (0.89), and shape factor (4.22) of soaked sorghum were increased as increase moisture content (Khedekar, 2013).

Bulk density, True density and Porosity measurement. The variation of bulk density and the true density of sorghum grain with moisture level are shown in Fig. 2. The bulk density of sorghum grain decreased linearly from 824 to 801 kg/mm^3. This decrease was due to the higher rate of increase in volume that relatively increased the weight (Konak *et al*., 2002). The true density of sorghum grain decreased linearly from 1560 to 1370 kg/mm^3 for sorghum grain, respectively. This decrease in true density may be due to a higher rate of increase in grain volume compared to weight increase (Karababa, 2006).

The porosity of sorghum grain varies with moisture level, as shown in Fig. 3. The porosity was calculated as a function of the bulk density and the true density of the grain. It was found to decrease linearly from 47.1 to 41.5 for sorghum grain (Baryeh, 2001).

As the moisture content of the soaked sorghum grain increased, the values of true density, bulk density, and porosity decreased (Amin *et al.,* 2004). The linear relationship between bulk density, true density, porosity and moisture content was developed. The linear regression equation was found to fit for sorghum densities and porosities (Table 1).

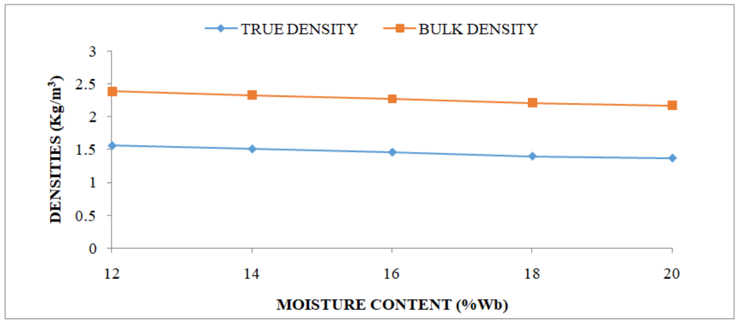

Fig. 2. Effect of moisture content on true density and bulk density of sorghum grain.

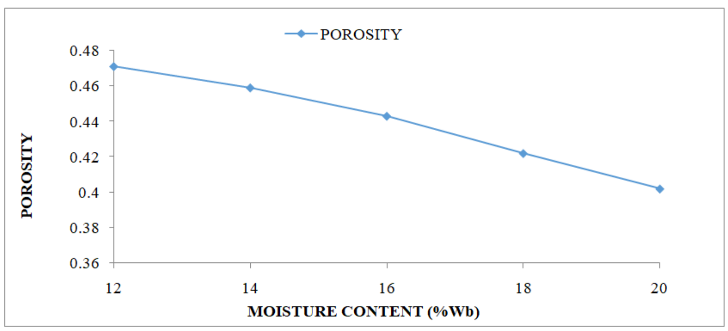

Fig. 3. Effect of moisture content on porosity of sorghum grain.

Table 1: Regression equations for physical properties of soaked sorghum.

Properties	Range	mx+c	R^2
Bulk density	0.801-0.824	-0.002x+0.845	0.991
True density	1.37-1.56	-0.024x+1.754	0.992
Porosity	0.402-0.471	-o.008x+0.544	0.988

CONCLUSION

1. The engineering properties of sorghum were measured at 12 to 20% (w.b.) moisture content.
2. At 12%, 14%, 16%, 18%, and 20% moisture content, the 1000 grain weight was found to be 39.52 g (±1 g), 47.92 g (±1 g), 52.76 g (±1 g), 61.06 g (±1 g), and 67.26 g (±1 g), respectively.
3. The length (4.30), width (3.87) and thickness (2.74) of the soaked sorghum were linearly increased.
4. The arithmetic mean diameter (3.62), geometric mean diameter (3.57), square mean diameter (6.17), equivalent diameter (4.44), degree of sphericity (0.84), aspect ratio (0.89), and shape factor (4.22), of soaked sorghum were increased as increased moisture content.
5. The variation of bulk density and true density of sorghum grain with moisture level. The bulk density of sorghum grain decreased linearly from 824 to 801 kg/mm^3. The true density of sorghum grain decreased linearly from 1560 to 1370 kg/mm^3, respectively.

FUTURE SCOPE

Engineering properties are those that are useful and required in the design and operation of various agricultural processing equipment, as well as in the design and development of other processing machinery. Cleaning, grading, drying, dehydration, storage, milling, handling, and transportation are examples of unit operations. Physical properties such as size, shape, surface area, volume, density, porosity, colour, and appearance are important when designing a specific machinery or determining the behaviour and handling of a product (Sahay and Singh 2001).

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Conflict of Interest. None.

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