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Physicochemical properties of sorghum grains

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Abstract

Sorghum (*Sorghum bicolor* L. Moench) is drought resistant crop used for its nutritional composition, climate resilience and preparation of gluten free food products. Sorghum use in value added goods is still very limited despite its known benefits. The current study was focused on investigation of the physicochemical characteristics of Parbhani cultivar of sorghum to evaluate its suitability for food applications. The sorghum grains of Parbhani cultivar were analysed for size, shape, bulk (apparent) density, true (particle) density, porosity, 1000-grain weight, hydration capacity, swelling capacity, sphericity and color aspects. Sorghum grains physical attributes provide key information for post-harvest handling and processing system design and optimization. The average size of grain measured were $4.19 \times 3.18 \times 2.12$ mm (L×W×T). Proximate composition presented sorghum as good source of protein and carbohydrates. The high carbohydrates content showed considerable potential of sorghum for starch extraction and the creation of functional food products while the low moisture content of grains implies favourable storage stability. Overall, the results show that sorghum grains have good nutritional and physicochemical qualities which support their use in sustainable cereal-based food systems.

Keywords: Sorghum, physicochemical properties, proximate composition, hydration capacity

Introduction

Jowar, scientifically referred to as *Sorghum bicolor* L, also called “King of millets” and ranked as fifth major significant cereal crop worldwide after wheat, rice, maize and barley. Sorghum is a tall annual herbaceous plant that is native to Africa and is found throughout Asia, Africa and the Americas. It is part of the Poaceae family. High yield, tolerance to drought and waterlogging, resistance to alkali and salt, resistance to thin lumps and resistance to high temperatures are some of its important traits (Alimagham *et al.*, 2024) [4]. Sorghum is vital to global agriculture because of its resistant properties against drought, salt and marginal soil conditions. It is particularly important in drought-prone regions where it is a vital cash crop. In other words, sorghum is serving as a staple food crop and it plays an important role in various industrial applications particularly in starch manufacturing (Zhang *et al.*, 2025) [24]. The nutritional composition of sorghum is affected by genetic, environmental and agronomic factors. These properties include a range of physical attributes such as grain size, color and weight in addition to their chemical composition which includes macronutrients (proteins, carbohydrates and fats), micronutrients (minerals like iron, zinc, potassium and calcium) and bioactive compounds (phenolics, tannins, and dietary fibre) (Singh *et al.*, 2024) [20]. Starch, protein, fat and non-starch polysaccharides are its main constituents; starch makes up the highest percentage usually between 55.6% and 70% while protein makes up between 7% to 15% (Khoddami *et al.*, 2023) [13]. Sorghum starch is mostly found in the endosperm and has a size range of 10 to 16 μ m. The physicochemical properties of sorghum grains such as porosity, true density and bulk density, thousand grains weight, Water absorption capacity, Swelling behavior and size are used for determination of processing quality and end product acceptability. Physical and chemical parameters of sorghum grains have significant correlations between grain weight, density, hardness and colorimetric parameter. Sorghum is ideal for gluten intolerance people because it is inherently gluten-free, it is even more relevant as a substitute cereal for those with non-celiac gluten sensitivity and celiac disease which impact millions of people worldwide. Glutinous sorghum is used widely around the world to produce sugar, paper, animal feed, and alcohol. It is also an essential raw ingredient for brewing (Jaćimović *et al.*, 2023) [11].

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According to Prasad *et al.* (2015) ^[18], a number of sorghum-based goods have lower glycemic loads than their corresponding wheat or rice products which could assist diabetic patients blood sugar levels. Significant heterogeneity in the physicochemical characteristics of sorghum grains has been highlighted by recent studies.

Materials and Methods

Materials

Sorghum grains used were of Parbhani Shakti and were procured from Parbhani (Maharashtra). The grains were cleaned, washed and dried in sunlight and kept in airtight glass containers until required again.

Physical properties of sorghum grains

Sorghum grains were assessed for the following physical parameters.

Bulk density

Bulk density was analyzed through the method of Jain & Bal., (1997) ^[12]. A 100 ml measuring cylinder was filled with a thousand randomly chosen sorghum seeds after they had been weighed. The cylinder was lightly tapped to allow proper settling of the material and the occupied volume was recorded. Bulk density was then determined by dividing the weight of the sample by its corresponding volume and calculated as g/mL.

True density

True density was evaluated for water displacement method. Pre weighed 1000 grains were transferred to a measuring cylinder filled with water up to fixed mark. After 24hr soaking in water weight and volume of soaked seeds were

recorded. True density was calculate das g/mL.

$$\text{True density, g/mL} = \frac{\text{Sample weight (g)}}{\text{Volume of displaced water (mL)}}$$

Porosity

The porosity was calculated from the following equation (Mohsenin, 2020) ^[14]:

$$\text{Porosity, \%} = \frac{(P_s - P_b)}{P_s} \times 100$$

Where,

P_s = True density, P_b = Bulk density

Thousand kernel weight

Thousand grains weight is the indicator of grain quality which was determined by weighing 100 sorghum seeds in an weighing balance with an accuracy of 0.001 g, the seeds were taken randomly from the bulk sample. The process was carried out in triplicate and average weight of 100 sorghum seeds was multiplied by 10 to calculated 1000 grain weight.

Hydration capacity

Hydration capacity (g/seed) was calculated by using the following method of Williams *et al.* (1983) ^[23]. A measuring cylinder with 50 mL of water was filled with a sample of 1000 seeds that had been weighed. The cylinder was covered with aluminium foil and kept at room temperature overnight to allow water absorption. After soaking, the water was drained and the hydrated seeds were weighed again. Hydration capacity was expressed as grams of water absorbed per seed (g/seed).

$$\text{Hydration capacity, \%} = \frac{1000 \text{ kernel wt(after soaking)} - 1000 \text{ kernel wt(dry)}}{1000 \text{ kernel wt(dry)}} \times 100$$

Swelling capacity

Swelling capacity (mL/seed) was determined by using the method of Williams *et al.* (1983) ^[23]. Thousand seeds were placed in a measuring cylinder and added the 50mL water.

$$\text{Swelling capacity, \%} = \frac{1000 \text{ kernel volume (after soaking)} - 1000 \text{ kernel volume(Initial)}}{1000 \text{ kernel volume(Initial)}} \times 100$$

Size

The size characteristics (length, width, and thickness) of sorghum grains were determined using a digital vernier calliper. Ten grains were randomly selected for measurement, and the procedure was performed in triplicate.

Sphericity

According to Mohsenin (1970) ^[15], the degree of sphericity of the grains was determined using a formula that shows the shape properties of sorghum grains in relation to a sphere of equivalent volume.

$$\text{Sphericity} = \frac{3\sqrt{LWT}}{L}$$

Where

L = Length of seed, W = Width of seed, T = Thickness of seed

Then it covered with aluminum foil, noted the volume of grains and kept for 24 h room temperature. Next day noted the volume of soaked seeds.

Color

Color is an important indicator of the quality of a product. The color was measured with a Hunter lab calorimeter. Lightness is indicated by the L^* value, where 100 denotes perfect white and 0 denotes black. The chromaticity dimensions are represented by the a^* value (redness/greenness) and the b^* value (yellowness/blueness).

Proximate analysis of sorghum grains

The moisture content, crude fat, protein, ash content and fibre of the sample were observed according to the standard analytical procedure of AOAC (2000) ^[1]. Total carbohydrate content was estimated by the difference method as described by AOAC (2000) ^[1] and expressed on a dry weight basis:

$$\text{Total carbohydrates (\%)} = 100 - [\text{crude fat (\%)} + \text{crude protein (\%)} + \text{crude ash (\%)} + \text{crude fibre (\%)}]$$

Results and Discussion

Physico-chemical properties of sorghum grain

a. Physical properties

The results of analysis of physical characteristics of sorghum grains are presented in Table 1.

Table 1: Physical properties of sorghum grains

Parameter	Value
Bulk density (g/cc)	0.821 ± 0.007
True density (g/cc)	1.282 ± 0.032
Porosity%	35.92 ± 1.228
Thousand grains weight (1000 seed)	20.47 ± 0.026
Hydration capacity (%)	79.75 ± 2.719
Swelling capacity (%)	43.79 ± 5.419
Size L×W×T (mm)	(4.19 ± 0.005×3.18 ± 0.007×2.12 ± 0.014)
Sphericity(mm)	0.72 ± 0.01
Colour (L*,a* and b*)	85.56 ± 0.45, 6.17 ± 0.06 and 29.33 ± 0.04

All the values are Mean ± SD of three replicates

Bulk density is an essential component influencing storage volume and mass of grain per unit volume including interstitial air gaps. These results for comparable millets varieties showed by Balasubramanian *et al.* (2010) [5]. The true density of the grain was determined to be 1.282 g/cc. True density measures the actual mass per unit volume of the solid grain material excluding interstitial air spaces is a fundamental parameter for assessing grain quality and maturity. The grain showed moderate air gaps between kernels with a porosity of 35.92%. Because it allows the flow of heat and moisture and lowers the risk of spoiling such porosity is beneficial during storage and aeration. Similar results have been shown for sorghum and other cereal grains where porosity typically varies between 30 and 40% based on environmental and other factors (Gosavi *et al.*, 2023) [9]. Sorghum grains have a thousand-grains weight of 20.47g which has an impact on the final quality of flour products and milling efficiency. The thousand-grains weight recorded for Parbhaniyoti sorghum grains was 33.97 g, for ParbhaniMoti 36.10 g and for Parbhani Shakti 27.56 g (Gosavi *et al.*, 2023) [9]. Sorghum grains have a hydration capacity of 79.75% indicating high ability to absorb water during soaking. The capacity of grains to absorb water is an essential indicator of its digestibility and cooking quality. These grains exhibiting comparatively high hydration capacity indicates that they will need less time to cook and could be appropriate for uses requiring quick rehydration. Hydration capacity of sorghum grains was higher than finger millets as reported by Panwar *et al.* (2024) [16]. According to Popoola *et al.* (2023) [17], the swelling capacity is also a sign of seed expansion that is favorable for improving the mouthfeel and the texture in food compositions. Also the high hydration and swelling capacities showed to efficiently absorb and hold water highlighting their suitability for starch extraction, cooking and the preparation of value-added products. Similar results have been reported in previous studies where improved water absorption properties were correlated with enhanced functional and processing properties of sorghum grains (Taylor & Duodu 2026; Abah *et al.*, 2020) [22, 2]. Sphericity value (0.72 mm) of sorghum grains indicated their moderately spherical shape. Similar size and sphericity value have been reported for different sorghum cultivar by

Gurracho *et al.*, 2024 [10]. Grain color is a crucial quality factor that influences consumer preference, flour appearance and applicability of sorghum. The color of sorghum grains were pearly white with slight reddish tint. The lightness of color of sorghum grain was indicated by a high L* value (85.56), a mild reddish colour is indicated by a low positive a* value (6.17) and considerable yellowness is indicated by a positive b* value (29.33). In general, light-colored sorghum grains are favored for making flour that has a reduced tannin content and is more palatable to consumers. Bodede, & Mabelebele (2022) [7] have reported similar color properties.

b. Proximate composition

The proximate constituents of sorghum grains are shown in Table 2. The various components of the proximate composition in grains including the moisture content, crude fat, the protein content, carbohydrates, crude fibre, ash content and so on were evaluated.

Table 2: Proximate composition of sorghum

Parameter	Value (%)
Moisture content	6.33 ± 0.05
Crude protein	8.77 ± 0.25
Crude fat	4.29 ± 0.01
Crude fiber	1.56 ± 0.01
Total ash content	1.4 ± 0.01
Total carbohydrates	76.63 ± 0.30

All the values are Mean ± SD of three replicates

Sorghum had a low moisture content (6.33%) indicating a good shelf life (Abdulkadir *et al.*, 2013) [3]. Generally low moisture content is preferred for longer storage life of mostly cereals and millets. The protein content of sorghum grains was 8.77% represented it as good nutritional value. The protein and fiber content in sorghum grains were lower as compared with amaranth (Sindhu and Khatkar 2016) [19]. The presence of crude fat and fibre further enhances its functional and health-promoting attributes whereas the ash content showed the availability of essential mineral constituents. Sulaiman *et al.* (2020) [21] studied sorghum grains and recorded comparable results exhibiting 7.5% moisture content, 10.50%, crude protein, 3.09% crude fat, 1.60% ash, and 74.43% carbohydrates. In another study 9.81% moisture content, the chemical contents of 12.27% crude protein, 4.37% crude fat content, 1.61% ash, and 66.38% starch were reported (Belhadi *et al.*, 2013) [6]. A high carbohydrate content stabilizes the well-being of consumers by providing energy for the metabolic process (Felicia & Deborah 2021) [8].

Conclusion

The results reported that sorghum grains have a favourable nutritional profile and desirable physicochemical properties which used for food processing and product development. The physical properties of sorghum grains including porosity, bulk density (apparent), true density, thousand grains weight, hydration capacity and swelling property were found to be beneficial for handling, processing and storage. The high lightness (L*) rating represents a good visual quality and makes the grain appropriate for producing light coloured flour which is often desired for a wide range of food products. The chemical analysis of sorghum grains observed favourable nutritional profile. In addition, the low

moisture content suggests improved storage stability. Overall the nutritional profile observed in this present study highlights the potential of sorghum as a valuable raw material for the of gluten-free product, functional foods and other value-added cereal-based formulations supporting its wider utilization in sustainable and nutritionally enriched food systems.

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