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# Extraction and characterization of sorghum (*Sorghum bicolor L. Moench*) starch

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**Abstract**: Four local Indian varieties of sorghum (CSH-9, CSH-5, Dadar and Parbhani) were subjected for proximate analysis and characterization of extracted starch. Starch from the above varieties was extracted by steeping, wet grinding and sedimentation process. Isolated starch was then characterized for amylose and amylopectin content, gelatinization temperature, viscosity, swelling power, solubility and water absorption capacity (WAC). Maximum amylose content of 19% was found for CSH-9, while Dadar had minimum amylose content of 11%.This gives an indication of utilization of low amylose or waxy starch variety like Dadar for pie-filling and puddings and high amylose variety of CSH-9 for gelling characteristics of cooled and cooked starches. Water absorption capacity (WAC) gave maximum value for Dadar and CSH-9, and minimum for CSH-5.So these varieties can be used in soups and in thickeners for their water holding capacity. Maximum viscosity was reported for Parbhani and CSH-9, and minimum for CSH-5 and Dadar. Gelatinization temperature was varied from 64$^{0}$C for CSH-9 to a maximum of 68$^{0}$C for Dadar and Parbhani.

**Keywords: Sorghum (*Sorghum bicolor L. Moench*), extraction of starch, proximate analysis, characterization of sorghum starch**

## Introduction

Sorghum (*Sorghum bicolor L. Moench*), the world's fourth major cereal in terms of production, and fifth in acreage following wheat, rice, maize and barley, is a staple food crop of millions of poor in semi-arid tropics (SAT) of the world. It is mostly grown as a subsistence dry land crop by resource limited farmers under traditional management conditions in SAT regions of the Africa, Asia and Latin America, which are frequently drought-prone and characterized by fragile environments. India grows the largest acreage of sorghum in the world followed by Nigeria and Sudan, and produces the second largest tonnage after the US. In most of the regions of India, it is cultivated both as a rainy- and post rainy-season crop. The yield and quality of sorghum produced worldwide is affected by a wide array of biotic and abiotic constraints (FAO, 1995; ICRISAT, 2004; Nadia *et al*., 2009).

It sustains the lives of the poorest rural people and often referred to as "coarse grain" or "poor people crop." However, with increasing world population and decreasing water supplies, it is foreseen as an important future crop. Although sorghum is major cereal crop and resembles corn in general composition, it is considered to be inferior to corn for food, feed and industrial use. Sorghum based food products occupy a low position in a diet due to poor grain quality attributes. The dark color, high fiber content, pronounced flavor, grittiness of flour and difficulty to cook into the soft products like bread, biscuit, cake and pastries, are some of the disadvantages. One way of using surplus sorghum is by way of producing starch and starch based sweeteners. The process is likely to be economical as sorghum is available on large scale with low cost. Sorghum grain contains starch ranging from 68-75% depending upon cultivar, region and climatic conditions. (Subramanian *et al*., 1994; Shinde, 2005; Singh *et al*., 2009)

Among carbohydrate polymers, starch is currently enjoying attention owing to its usefulness in different food products (Taylor *et al*., 2006). Sorghum, like other cereals, is rich in starch–a major storage form for carbohydrates–which makes up about 60-80% of normal kernels and has excellent potential for industrial applications (Zhang *et al*., 2003; Elmoneim *et al*., 2004; Claver *et al*., 2010). Starch plays an important role in physical, chemical and nutritive attributes of the finished foods.

At present corn and tapioca are the major sources of starch. The availability of corn and tapioca to Indian starch industry is decreasing, because of its increased demand by industries involved in the production of breakfast cereals and snacks. Sorghum being cheaper than corn and tapioca as it can be grown with minimum inputs; it can be exploited as an alternative starch source for diverse industrial

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applications. So the objective of present work was to characterize some of the local sorghum varieties for starch production to be used for industrial exploitation (Shinde, 2005; Singh *et al*., 2007, Singh *et al*., 2009; Claver *et al*., 2010).

## Materials and Methods

### *Proximate analysis of sorghum grains*

Sorghum cultivars CSH-5, CSH-9, Dadar and Parbhani were procured from the Sorghum Research Unit, Dr. Panjabrao Deshmukh Agricultural University, Akola, Maharashtra State, India. Proximate analysis for moisture, ash, protein, crude fiber, fat, total carbohydrate and starch were carried out by standard methods of AOAC (2000).

### *Extraction of starch*

Starch was extracted by using the method of Singh *et al*. (2009) with some modifications. Sorghum grain (100 g) was steeped in 200 ml of NaOH (0.25% w/v) at 5°C for 24 h. The steeped grains were washed and ground with an equal volume of water using a blender for 3 min. The slurry was filtered through a 200-mesh screen. The residue on the sieve was rinsed with water. Grinding and filtering were repeated thrice on this material. After rinsing, residue was discarded. The filtrate was allowed to stand for 1 h. The filtrate was centrifuged at 6000 rpm. for 10 min. The grey colored, top protein-rich layer was removed using a spatula. Excess water was added to resuspend the sample, and centrifugation was done again for 5 min. Washing and centrifugation were repeated several times until the top starch layer was white. The starch was dried for 24 h at 40°C. Percentage recovery was determined on the basis of 100 gm sample.

### *Characterization of sorghum starch*

#### *Amylose and amylopectin content*

Amylose and amylopectin content of extracted starch samples were determined by using the method of Williams *et al*. (1970) with optical density measurement at 620 nm.

#### *Gelatinization temperature*

Gelatinization temperature was determined by microscopic staining method (Lamb and Loy, 2005) using monocular microscope (Model RMH-4, Radical Instruments, India) using 0.2% w/v of Congo red (CI 22120, CI name 'Direct Red 28'; empirical formula $C_{32}H_{22}N_6O_6S_2Na_2$) solution. Starch samples were dispersed in water at 0.5% concentration in test tube. Suspension was heated at 50°C. Small quantity of this was taken on glass slide using a pipette, over which a small drop of Congo red solution was added. This was repeated at each 5°C increment up to 60°C and later with 2°C increment up to 75°C. The stained slides were observed under microscope. The temperature at which more than 80% starch granules seen red was reported as gelatinization temperature of starch sample. Three replicate samples were used in this determination (Sakonidoua *et al*., 2003).

#### *Swelling power and water solubility index*

The estimation of swelling power and water solubility index were carried out according to the method of Leach *et al*. (1959) with some modifications. A suspension of 500 mg of starch and 20 ml of distilled water was heated in a water bath at 50°C, 60°C and 70°C for 30 min. The suspension was then cooled rapidly at room temperature and centrifuged at 5000 r. p.m. for 20 min. After this 10 ml Aliquot was pipetted into a weighing dish and dried at $120^0$C for 2 hr to determine the soluble content. The remaining supernatant was carefully removed by suction and weighed to determine the water solubility index of starch granules. Swelling power (%) was calculated with corrections for soluble.

#### *Viscosity*

Viscosity was measured by method of Bechtel and Fischer (1949) using a special instrument known as ford viscosity cup No. 4.( EZ Series Viscosity Cups, Standard Model VC005.003, EZ EM Corp. ,Westbury, NY). In this cup the semi liquid starch sample (5% W/W at 250C ) made with water was filled at $25^0$C. After some time the cup was allowed to empty by allowing liquid paste to come out through orifice which was located at the bottom of cup. The time required for emptying the cup was measured carefully using digital stopwatch. By calculating the time in seconds, viscosity can be determined in Centistokes (cSt) using ford cup viscosity conversion chart. The experiment was repeated twice and the average time of flow was calculated.

#### *Water absorption capacity*

Water absorption capacity (WAC) was estimated by method of Claver *et a*l. (2010) by dispersing the starch samples in water for 2 hours followed by measuring final weight.

## Results and Discussion

Chemical composition of sorghum grain with respect to moisture, ash, crude fiber, protein, total carbohydrate and fat content are presented in Table 1. Protein content of Dadar and Parbhani was higher than CSH-5 and CSH-9 varieties. CSH-5 and CSH-9 varieties were better for starch extraction than Dadar and Parbhani varieties. These results were comparable with results of Tester *et al*. (2004) and Thongngam and Chanapamokkhot (2007). Another crucial component is fat. The role of lipid is that it can affect the swelling and pasting properties of starch (Goering *et al*., 1975; Thongngam and Chanapamokkhot, 2007). Maximum fat % was found in Parbhani variety followed by CSH-9, CSH-5 and Dadar varities. Maximum carbohydrate was found in CSH-5 variety i.e. 76.20% followed by Parbhani, Dadar and CSH-9 verities as 73.35, 71.89 and 70.65% respectively. Percentage of starch and its recovery are presented in Table 1. Maximum recovery of starch was 55% for Parbhani variety followed by 50% for CSH-9 variety.

**Table 1.** Proximate analysis of sorghum grain

| Parameters | Varieties | | | |
|---|---|---|---|---|
| | CSH-5 | CSH-9 | Dadar | Parbhani |
| Moisture (%) | 8.10 | 9.80 | 9.99 | 8.51 |
| Ash (%) | 1.55 | 1.75 | 1.09 | 0.92 |
| Crude fiber (%) | 1.40 | 2.70 | 1.90 | 1.58 |
| Protein (%) | 8.90 | 9.60 | 11.02 | 10.65 |
| Total carbohydrate (%) | 76.20 | 70.65 | 71.89 | 73.35 |
| Fat (%) | 2.50 | 2.70 | 2.30 | 2.80 |
| Starch percentage (%) | 72.00 | 70.00 | 72.00 | 72.00 |
| Starch recovery (%) | 40.00 | 50.00 | 45.00 | 55.00 |

**Table 2.** Amylose-amylopectin content and gelatinization temperature of sorghum starch

| Varieties | Amylose content (%) | Amylopectin content (%) | Gelatinization Temperature ($^0$C) |
|---|---|---|---|
| CSH-5 | 12.96 | 87.04 | 66.00 |
| CSH-9 | 18.72 | 81.28 | 64.00 |
| Dadar | 10.80 | 89.20 | 68.00 |
| Parbhani | 12.96 | 87.04 | 68.00 |

The amylose and amylopectin content could play a major role to swelling, pasting properties, viscosity and gelatinization temperature (Tester and Morrison, 1990; Choi and Shin 2004; Thongngam and Chanapamokkhot, 2007) and gel firmness of starch (Thongngam and Chanapamokkhot, 2007). Amylose and amylopectin content are presented in Table 2. Maximum amylose content i.e. 18.72% was found in CSH-9 followed by CSH-5, Parbhani and Dadar with 12.96%, 12.96% and 10.8% amylose content respectively; while trends for amylopectin was reverse for these varieties.

Gelatinization temperatures of all varieties are presented in Table 3. Gelatinization temperature of 68$^0$C was found for Dadar and Parbhani while minimum of 64$^0$C was observed for CSH-9. Gelatinization temperature was affected by amylose and amylopectin ratio (Olkku and Rha, 1978). The high gelatinization temperature for Dadar and Parbhani may be due to high amylopectin content where the branches prevent the degree of association for gel formation (Gaffa *et al*., 2004).

**Table 3.** Swelling power and water solubility index of sorghum starch

| Characteristics | Varieties | | | |
|---|---|---|---|---|
| | CSH-5 | CSH-9 | Dadar | Parbhani |
| Swelling power at 50 $^0$C (g/g) | 11.60 | 12.20 | 13.00 | 13.20 |
| Swelling Power at 60 $^0$C (g/g) | 13.40 | 14.10 | 15.10 | 15.80 |
| Swelling power at 70 $^0$C (g/g) | 17.60 | 16.60 | 17.20 | 17.20 |
| Water Solubility Index at 50 $^0$C (%) | 14.50 | 14.80 | 13.6 | 13.20 |
| Water Solubility Index at 60 $^0$C (%) | 16.10 | 15.10 | 14.30 | 15.10 |
| Water Solubility Index at 70$^0$C (%) | 17.20 | 16.60 | 16.4 | 16.00 |

Swelling power and water solubility index are presented in Table 3. Swelling power of starch is attributed to the strength and character of the micellar network within the starch granule. As the temperature was increased, the starch granules were vibrated more vigorously, breaking intermolecular bonds and allowing hydrogen-bonding sites to engage more water molecules. Swelling power and water solubility index provide evidence of the magnitude of the interaction between starch chains within both the amorphous and crystalline domains (Tang *et al*., 2004; Singh *et al*., 2007; Claver *et al*., 2010). The extent of interaction was influenced by the ratio and characteristics of amylose and amylopectin in terms of molecular weight distribution, degree of branching, length of branches and conformation of molecules (Ratnayke *et al*., 2002; Singh *et al*., 2009). Water solubility index and swelling power at different temperatures at 50$^0$C, 60$^0$C and 70$^0$C were determined, which were increased with increase in temperature. Rapid rise in swelling power was observed from 60 to 70$^o$C, where the gelatinization was occurred.

**Table 4.** Viscosity and Water absorption capacity of sorghum starch

| Varieties | Viscosity (Second) | Water absorption capacity (%) |
|---|---|---|
| CSH-5 | 8.00 | 88.0 |
| CSH-9 | 9.00 | 92.4 |
| Dadar | 8.00 | 97.4 |
| Parbhani | 10.00 | 96.0 |

Viscosity is presented in Table 4. Maximum viscosity was observed for Parbhani followed by CSH-9. Cooling causes increase in viscosity due to retrogradation while viscosity decreases with increase in temperature and shear rate (Miles *et al*., 1985; Fitzgerald *et al*., 2003; Sang *et al*., 2008). Such properties are important for mixing and pumping operations in industries. Water absorption capacity (WAC) at different temperatures was recorded and presented in Table 4. Water absorption capacity was increased with increase in temperature. It helps in finding out the water holding power of starch i.e. when used in soups and thickeners.

## Conclusion

CSH-5 and CSH-9 varieties were better for starch extraction than Dadar and Parbhani varieties. As the amylose content of Dadar variety was found less, this variety can be utilized for the preparation of for pie filling and puddings where as the amylose content of CSH-9 variety was found high, so this variety can be utilized for the gelling characteristics of cooled and cooked starches. As higher water solubility index and swelling power at higher temperature have important role in determining textural, pasting and thickening properties of starch based preparation, so for these applications Dadar and Parbhani verities should preferred. As the water absorption capacities of Dadar and Parbhani verities were more, these verities should be preferred in the preparation of soups and as a thickener or binder. The study of viscosity will be helpful for mixing and pumping operations in industries. The present findings throw a light on extraction and utilization of starch from sorghum instead of corn for its commercial applications in various food industries.

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