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STUDIES ON EFFECT OF SOAKING TIME, TEMPERATURE AND pH ON THE YIELD OF SORGHUM STARCH (*SORGHUM BICOLOR*) VARIETY PVK-801

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ABSTRACT
The suitability of sorghum as a source of starch was investigated. The effects of soaking time, temperature and pH on the yield of starch were optimized and its functional and rheological properties were studied. The sorghum grain flour contained 74.50% starch. Soaking time of 20 h, temperature of 50°C and pH of 4.5 resulted in maximum yield (75.5%) of starch.The solubility and swelling of sorghum starch were maximum at 90°C viz. 19.25% and 18.10% respectively. The starch at 10% level yielded an apparent viscosity of 1998.50 Cps at 90°C using shear rate of 4.51 S^{-1}.

INTRODUCTION

Sorghum (*Sorghum bicolor*) known as jowar is the third largest cultivated crop in India after rice and wheat and is fifth in the world after rice, wheat, corn and barley. Sorghum is used both as food and feed. Starch is the major constituent of sorghum endosperm. Starch plays an important role in physical, chemical and nutritive attributes of the finished foods. The principal functions that specially starch perform in food are adhesion, antistaling, binding, clouding, dusting, emulsification, flow aid, foam strengthening, jelling, glaze forming, moisture holding, processing aid, shaping, stabilizing, texturizing and thickening (Smith and Bell, 1986).

Sorghum grains contain starch ranging from 68-75% depending upon cultivar, region and climatic conditions (Subramanian *et al.*, 1994, Shinde, 2005 and Singh *et al.*, 2009). However yield of starch from sorghum depends on the temperature and time of soaking in water and its pH. The yield of starch from sorghum grains ranges from 62.6 to 73.3% (Subramanian and Jambhunathan, 1981). Wankhede *et al.* (1977) reported 60.25% yield of starch while Shinde (2005) reported 70.30% from sorghum grains. Wankhede *et al.* (2005) obtained maximum yield of starch when sorghum grains were steeped in distilled water for 20 h at 50-60°C.

For the extraction of starch *Parbhani Sweta* technically known as PVK-801 a kharif sorghum variety with a multitude of characteristics which made it suitable for isolation of starch. It is a variety of hybrid look with a higher yield, medium bold grains and resistant to mold attack. It is a rich source of carbohydrates in which starch alone contributes about 75.50%, which is significantly higher than other varieties of kharif sorghum (Syed Ismail *et al.*, 2000). The main object of this study was to extract starch from this variety by optimizing the extraction variables viz soaking time, temperature and pH and also to study the functional and rheological properties.

MATERIALS AND METHODS

Sorghum variety *Parbhani Sweta* (PVK-801) was obtained from Sorghum Research Station, Marathwada Krishi Vidyapeeth, Parbhani.

Proximate composition

The proximate composition of sorghum flour and starch was estimated by methods of AOAC (2000).

Isolation of sorghum starch

Sorghum grains (50g) were cleaned and steeped in water (1:2 w/v) for 20 h at 50°C and pH 4.5 with addition of 750 ppm KMS. In addition, the mercuric chloride was added in very low concentration (0.001M) to arrest the á-amylase activity during steeping. The steeped grains were washed thoroughly with water and then subjected to homogenization. The resultant slurry was filtered through muslin cloth followed by sieving through standard mesh sieve (150μ). The crude starch was purified by suspending in distilled water (1:5) and sodium chloride added to denature the protein. It was kept for shaking for 1 to 2 h and the denatured protein was removed by centrifugation at 4000 rpm for 15 min, washed with isopropanol and air dried for overnight.

During the experiments attempts were made to standardize various extraction parameters *i.e.* soaking time (5, 10, 15, 20, 25, 30 and 35 h), temperature (30, 40, 50, 60, 70, 80 and 90ºC) and pH (7.0, 6.5, 6, 5.5, 5.0, 4.5, and 4.0) of the medium for the production of sorghum starch.

Rheological properties of starch

Viscosity

Viscosity was determined by Haake's Rotoviscometer (RV-20 model, Haake Germany). It is distinguished by its scientifically based measuring principle and wide ranges of shearing stresses and shearing rates to obtain meaningful results.

The observations were recorded for %ô with respect to % D reading over different deformation speed ranging from 4.51 s^{-1} to 451 s^{-1} (total 10 number of shear rates) by using spindle MV-II sensors cylinder system.

The calculations for shearing stresses were made by using following equation. The shearing stress (ô) of the materials expressed as under

ô = %ô × A

Where,

ô = Shearing stress (dynes / cm^2)

%ô = Displaced shear stress reading, and

A = shear stress factor

The shearing rate (D), is also designated as deformation speed and is expressed as under

D = % D x M

Where,

D = shearing rate (s^{-1})

% D = present shear rate

M = shear rate factor

The spindle constants A and M for particular spindle (MV-II) were obtained from the manual of the instrument supplied by the manufacturing company (A = 3.76, M = 4.51). The calculation for apparent viscosity (μ) were done by using following formula

μ = ô/D or Cp = μ x 1000

Where,

μ = apparent viscosity (Pa.s)

ô = shearing stress (dynes / cm^2)

D = shearing rate (s^{-1})

Cp = Pa.s x 1000

The effect of different temperatures (60-90ºC) and after cooling to room temperature (RT) on viscosity profile of starch at 10% (w /v) at different shear rates have been carried out.

Swelling and solubility characteristics of sorghum starch

The estimation of swelling and solubility power of sorghum starch was carried out according to 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 50ºC, 60ºC and 70ºC for 30 min. The suspension was then cooled rapidly at room temperature and centrifuged at 5000 rpm for 20 min. After this 10 ml aliquot was pipetted into a weighing dish and dried at 120ºC for 2 h to determine the soluble content. The remaining supernatant was carefully removed by suction and weighed to determine solubility index of starch granules. Swelling power (%) was calculated with corrections for soluble.

Statistical analysis

Statistical analysis of the data was done by using Snedecor and Cochran (1980).

RESULTS AND DISCUSSION

Proximate composition of sorghum grains

The results (Table 1 and 2) revealed that the sorghum grain contained 74.50% starch, 9.78% protein, 2.42% fat and 1.58% ash whereas the sorghum starch contained 91.80% total carbohydrates, 1.10% protein, 0.90 fat, 0.73% crude fiber and 0.23% ash respectively. These results were comparable with results of Udachan *et al.* (2012) on sorghum with slight changes which could be because of varietal differences.

Standardization of starch extraction parameters

The effects of soaking time, temperature and pH on the yield of starch were attempted. The results obtained are presented in Table 3. The results indicated that there was considerable increase in the yield of starch as soaking time increased from 5 to 20 h and thereafter it decreased. The optimum yield of 75.50% was obtained at 20 h of soaking time. This could be

Table 1: Proximate composition of sorghum grain flour

Composition	Moisture(%)	Ash(%)	Crude fat (%)	Protein(N*6.25)(%)	Crude fiber(%)	Starch(%)
Sorghum grain flour	9.24	1.58	2.42	9.78	2.65	74.50

*Each value is the average of five replications.

Table 2: Proximate composition of sorghum starch

Composition	Moisture(%)	Ash(%)	Crude fat (%)	Protein(N*6.25)(%)	Crude fiber(%)	Total carbohydrate(%)
Sorghum starch	9.80	0.23	0.90	1.10	0.73	91.80

*Each value is the average of five replications.

due to the entry of soaking water in the porous tip cap and moves quickly in to voids in the pericarp by capillary action. Once the equilibrium is attained further diffusion of water stops as the diffusion of water in to endosperm and germ follows standard diffusivity law. These results are similar with results reported by Singh and Eckhoff (1996). The result revealed that maximum yield of 75.30% starch was obtained at 50ºC soaking temperature. When the temperature increased from 30ºC to 50ºC the yield of starch also increased significantly. However, beyond 50ºC it decreased. At hyper physiological temperature of 50 – 60ºC, protein matrix has the highest degree of globulation, which has directly related to the maximum starch recovery on grinding. The results are in good agreement with those reported by Singh and Eckhoff (1996).

Results further indicated that there was significant decrease in the yield of starch as pH increased from 4.0 to 7.0 and thereafter increased. The optimum yield of 75.20% was obtained at pH of 4.5. This may be attributed to the fact that the acidic pH would have helped in maintaining the bisulfite ion equilibrium and denatured proteins so as to release the maximum amount of starch. These results are in good agreement with the result reported by Cabrales *et al.* (2006) on corn hybrids starch.

Table 3: Effect of soaking time, temperature and pH on the yield of sorghum starch

Parameter Soaking time (h)	Yield of starch (%)
5	55.40
10	61.40
15	67.40
20	75.00
25	70.60
30	67.60
35	65.60
S.E±	0.1473
C.D at 5%	0.4261
Temperature (ºC)	
30	70.10
40	71.82
50	75.30
60	72.20
70	70.00
80	69.00
90	67.00
S.E±	-
C.D at 5%	-
pH	
7.0	47.80
6.5	50.40
6.0	54.80
5.5	60.40
5.0	64.80
4.5	75.20
4.0	67.20
S.E±	0.1423
C.D at 5%	0.4115

*Each value is the average of five replications.

Rheological characteristics of starch

Viscosity

In order to assess the importance and physibility of starches in food and other industries, the viscosity profile is generally considered as one of the important parameters to decide the performance of the said sorghum starch for that particular industry. Knowledge of flow characteristics is important because of their effect on the finished product viz. mouth feel, texture and other properties. The data on flow behavior of starch solution at various temperatures are presented in Table 4. The results revealed that viscosity increased significantly when the temperature of starch was increased from 60ºC to 90ºC. The starch at 10% level yielded maximum apparent viscosity of 1998.50 Cps at 90ºC using shear rate of 4.51 S^{-1} than other shear rates. This may be due to variation in amylose and amylopectin content ratio and the type of starch either native or modified. The starch in the present study is a native one which showed many fold increase in viscosity over the modified one. However, Shinde (2005) reported viscosity of 2051.3 Cps at 90ºC of carboxymethyl sorghum starch. The differences in the present study and of Shinde (2005) could be due to varietal and experimental errors.

Swelling and solubility characteristics of sorghum starch

The swelling and solubility characteristics are of significance in understanding the organization of molecules within the granules. The results on per cent solubility and swelling power (Table 5) indicated that the starch solubility was increased from 0.65 to 19.25% with increasing the temperature from 40 to 90ºC and was maximum (19.25%) at 90ºC. The resultant increase at higher temperature may be attributed to the pasting / gelatinization temperature of respective starch. The increase in solubility may be mainly due to the dissociation of hydrogen bonds in amylose of the starch, which possess micelle structure units together. Therefore an enhancement in the temperature was found to accelerate the destruction rate of hydrogen bonds during heating of starch paste. The swelling power of starch was also increased from 1.64 to 18.10% when temperature was increased from 40 to 90ºC, its maximum (18.10%) at 90ºC. The abrupt increase in swelling was due to the effect of temperature on the uncoiling of starch molecules which found to facilitate water penetration inside the starch granules and its molecule, bound to the active center of the

Table 4: Effect of temperature on flow behavior of sorghum starch

Temperature(ºC)	Apparent Viscosity (Cps) Shear rates(s^{-1})				
	4.51	34.90	94.70	270	451
60	-	1.40	2.50	4.80	12.75
70	25.60	32.17	38.65	44.50	60.25
80	55.65	66.63	72.15	76.80	84.50
90	1998.50	1392.75	715.20	602.75	372.30
After cooling to room temp.	4322.50	2517.50	1152.50	870.00	641.25

*Each value is the average of five replications.

Table 5: Solubility and swelling properties of starch at varying temperatures

Parameter	Temperature °C					
	40	50	60	70	80	90
Solubility(%)	0.65	0.82	2.70	7.20	12.40	19.25
Swelling power(%)	1.64	1.92	3.70	6.25	12.70	18.10
S.E±	0.1315					
C.D at 5%	0.4120					

*Each value is the average of five replications.

starch which intern, resulted in an increase in swelling power of starch molecule. The results of present investigation are in good conformity with the results reported by Hathaichanok and Masuban (2007).

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