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Boiled Sorghum Characteristics and their Relationship to Starch Properties

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Summary

Traditional methods of boiled sorghum preparations are described. The cooking quality of boiled sorghum prepared from dehulled grain of 25 cultivars was evaluated using laboratory procedures. The percent increase in volume and weight of grains due to cooking, time required for cooking, texture of the cooked grain, and overall acceptability of the cooked product varied among the genotypes. Color, taste, texture, and keeping quality of boiled sorghum were evaluated using a taste panel. Swelling power, solubility, and inherent viscosity of starch were determined for 12 cultivars. The relationship between starch characteristics and cooking quality of boiled sorghum was studied. Cooking quality characteristics of boiled sorghum were significantly correlated with the swelling power and solubility of the starch.

Sorghum grains are an important source of food for several million people in Africa and India. The status of sorghum has long been underrated and is considered as a poor man's food. Subramanian and Jambunathan (1980a) carried out a survey of sorghum utilization methods in India and reported on the consumption pattern of boiled sorghum. In this paper, an attempt has been made to describe the traditional method of boiled sorghum preparation and laboratory evaluation of the boiled sorghum quality of 37 cultivars.

Rice is preferred over sorghum in certain regions, because it is comparatively easy to process and cook. The cooking and eating quality of rice have been studied in detail (Juliano 1979). The processing and cooking of sorghum take more time and fuel than rice (Desikachar 1975). Sorghum grains are used for food in several ways in India and African countries. In India, particularly in southern regions, boiled sorghum (rice-like) called *annam* or *soru* is one of the common products prepared and it accounts for about 10% of the total sorghum grain produced.

A similar product of sorghum is known as *khicuri* in Bangladesh, *lehata wagen* in Botswana, *kaoliang mi fan* in China, *nufro* in Ethiopia and *oka baba* in Nigeria (Subramanian and Jambunathan 1980 b).

A brief account of information obtained through a survey (Subramanian and Jambunathan 1980) is given in this paper. The boiled sorghum is mostly preferred by the village population rather than the urban or semiurban population. As a finished product, it is not usually sold in restaurants. Boiled sorghum is consumed mostly by adults and generally is not given to children below the age of 5 years. The freshly prepared product is consumed with dhal, sambar (a sauce prepared with tamarind, dhal and vegetables), buttermilk with pickles, or onion and green chillies for lunch or supper. Sometimes, it is stored overnight by adding water and consumed the next morning with buttermilk. The nutritive value may vary according to the cultivar used and the degree of dehulling, etc. The nutritional composition of boiled sorghum has been reported by Pushpamma and Geervani (1981).

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Traditional Methods of Preparation of Boiled Sorghum

Dehulling

Sorghum is traditionally used as boiled sorghum after dehulling the grains (Subramanian and Jambunathan 1980a). The color of the grains normally used varies, i.e., white, yellow, and red. The use of dehulled grain gives the product an appearance resembling polished rice. The grains are moistened and pounded in a stone mortar with a wooden pestle. The loosened bran is winnowed out and the dehulled product is used for food. The husk is used as cattle feed or is fermented in water, which is used in some food product. Generally, dehulling is done whenever needed and the grains are cooked the same day. Dehulled sorghum grain is not stored for more than 2 or 3 days.

Cooking

The dehulled grain is cooked in water in the proportion of 1 : 3. Sometimes the grains are also soaked overnight in water to soften the grain and cooked the next morning in water (Subramanian and Jambunathan 1980a). The cooking is preferably done in an earthen pot, which is heated using firewood. The grains are cooked to softness and the excess water is drained off. Depending upon the economic status of the consumer, cooking of sorghum is done with the addition of spices, mungbean, chickpea, groundnut, etc. The cooked product has to be fluffy, uniform yellow or creamy white in color, with a sweet taste. The cooked product should not be sticky with poorly defined kernels. It is also desirable that the solids dispersed into gruel be a minimum.

Standard Laboratory Procedure

Sorghum cultivars grown at ICRISAT Center during the postrainy season of 1979 were used. A quantity of 300 g samples was dehulled using a wooden mortar and pestle. The husk and brokens were removed by winnowing, and dehulled grains were used for cooking.

1. Dehulled grain samples were dried to a moisture content of about 10%. Grain characteristics such as corneousness, color and 100-grain weight were recorded.

2. The initial volume of 20 g of dehulled samples used for cooking was measured. The samples were transferred to a 500 ml beaker, to which 200 ml distilled water were added. The contents were allowed to boil on a hot plate maintained at 350° C. The completion of cooking was tested by pressing the grains between two glass slides and examining the loss of opaqueness in the center of the grain. The time required for completion of cooking was recorded. The excess water was decanted. The volume and weight of cooked samples were measured after cooling for 30 min at room temperature. The increases in volume and weight of the product were calculated as percent increase over initial volume and weight of the grain.

Evaluation of Organoleptic Qualities

The boiled sorghum (*soru*) quality of the grain was evaluated with the help of six selected farm women at Bhavanisagar (South India). Since boiled sorghum is a traditional product, persons who regularly consumed sorghum as a boiled product were selected as panelists. The panelists were requested to evaluate independently for color, taste, and texture on a scale of 1 to 3, where 1 was good and 3 was poor. The keeping quality was judged by the same panelists for acceptability, after storing the product overnight at room temperature. The keeping quality was judged for firmness of the product without off-flavor.

Evaluation of ISFQT Samples

Using the standard procedures mentioned, 25 genotypes of the International Sorghum Food Quality Trials (ISFQT) were evaluated in duplicate for cooking quality and organoleptic properties. The time required for cooking 20 g samples was highly variable, which ranged from 33 to 79 min. The increase in volume varied from 283 to 466% and increase in weight varied from 212 to 340%. The texture of the cooked grain which was subjectively scored, varied from 1 to 3.4 (Table 1).

The data on *soru* quality characters of the 25 cultivars are given in Table 2. The data indicate that *soru* from white or creamy colored grains was preferred. Although the grain with testa and colored pericarp had been dehulled before cooking, the final product was unacceptable. Boiling of

Table 1. Variability for grain and cooking quality attributes in traditionally dehulled sorghum grain.[a]

Attribute	Mean	± S.E.	Range	
			Minimum	Maximum
Corneousness[b]	2.5	0.17	1.0	5.0
Grain weight (g 100 grains)	2.9	0.16	2.1	6.4
Time required for cooking (min)	45	2.2	33	79
Percent increase in weight	274	6.2	212	340
Percent increase in volume	362	8.8	283	466
Cooked grain texture[c]	2.3	0.11	1.0	3.4

a. Based on observations from 25 cultivars of the International Sorghum Food Quality Trial. Mean of two independent determinations.
b. Corneousness of endosperm was evaluated on a scale of 1 to 5, where 1 = 80 to 100% corneous and 5 = 0 to 20% corneous.
c. Cooked grain texture was evaluated on a scale of 1 to 5, where 1 = soft and 5 = hard.

Table 2. *Soru* quality parameters of 25 sorghum cultivars.[a]

Cultivar	Grain color	*Soru*[b]			
		Color appeal	Taste	Texture	Keeping quality
M35-1	Pale yellow	1.7	1.2	1.1	1.6
CSH-5	Pale yellow	1.5	1.4	1.6	1.3
M5009	Pale yellow	1.5	1.5	1.8	1.7
M50013	Pale yellow	1.3	1.5	2.0	2.1
M35052	Pale yellow	1.2	1.7	1.5	1.7
M50297	Pale yellow	1.6	1.8	2.0	1.3
P-721	White	2.6	2.7	2.7	3.0
CO4	Red	1.9	1.6	1.6	1.1
Patcha Jonna	Yellow	2.4	2.3	2.4	2.3
Mothi	Pale yellow	1.2	1.5	1.7	1.6
E35-1	White	1.3	1.7	1.7	1.8
IS-158	White	2.0	2.0	3.0	2.7
WS-1297	Light grey (testa)	3.0	2.1	1.8	2.4
Swarna	Pale yellow	1.9	1.9	1.9	1.7
S-29	White	1.1	1.2	1.1	1.2
S-13	Pale yellow	1.0	1.0	1.3	1.7
IS-2317	Light grey (testa)	2.9	1.2	1.0	1.2
IS-7035	White (testa)	3.0	2.6	2.8	1.6
IS-7055	Reddish brown (testa)	3.0	1.8	1.1	2.0
IS-9985	Yellow	2.0	2.1	2.3	1.3
IS-8743	Dark yellowish brown	2.0	2.0	2.0	2.0
Dobbs	Brown (testa)	3.0	3.0	3.0	3.0
CS-3541	Pale yellow	1.1	1.7	1.8	1.9
Segaolane	Pale yellow	1.7	1.6	1.6	1.3
Market-1 (Ouagadougou)	White	1.5	2.0	2.0	1.8
Mean ± S.E.		1.9 ± 0.12	1.8 ± 0.09	1.9 ± 0.11	1.8 ± 0.10

a. All characters rated on a scale of 1–3 where 1 = good and 3 = poor.
b. Mean of two independent observations; each cultivar was evaluated two times by six panelists at Bhavanisagar.

grains caused leaching of pigments into the water and into the endosperm (Waniska 1976). However, the texture of the cooked product from soft endosperm types like IS-2317 and IS-7055 was very much preferred in addition to those of CO-4, M35-1 and S-29. The keeping quality of *soru* from the local variety CO-4 was the most desirable followed by that from IS-2317, S-29, M35-1 and Segaolane. The waxy grains (IS-158) yielded a sticky product.

Cooking Quality and Starch Properties of 12 Cultivars

The cooking process for boiled sorghum appears to be mostly a physical phenomenon. The chemical factors, i.e., amylose and amylopectin, were considered to be important criteria of grain quality of milled rice (Juliano 1979). Since boiled sorghum is similar to rice, analogous studies were undertaken on the cooking and starch characteristics of 12 sorghum cultivars including a waxy line, IS-158. The grain samples used in the study were obtained from the postrainy season harvest of 1979, except for two market samples.

The variation in cooking quality of boiled sorghum for the above 12 cultivars as evaluated by the standard laboratory procedures is given in Table 3. The hardness of the dehulled grain varied from 1.9 to 4.7 kg/cm² though the range in hardness of whole grain was 5.6 to 8.5 kg/cm². The cooking time ranged from 33 to 42 min. The volume expansion expressed as percent increase over initial volume of the grain was from 150 to 400. Swarna and Market-2 showed higher values, while waxy line IS-158 recorded the lowest value. Variation for increase in the weight of cooked grains ranged from 124 to 186%. There was wide variation between cultivars for gruel solids extracted into the cooking water (Table 3). Gruel solids is desired to be minimal coupled with soft cooking from a nutritional point of view. The quality of boiled sorghum was evaluated by three trained panelists using a scale of 1-5, where 1 is more acceptable. The product with pale yellow color without stickiness was rated good, which is similar to the conclusion obtained from the consumer panel. Genotypes M35-1, Market-2, Swarna, CSH-8, Local White and SPV-351 produced acceptable boiled sorghum. The waxy line (IS-158) and NK-300 produced an unacceptable product.

Starch was isolated from the whole grains

Table 3. Grain characteristics and cooking qualities of boiled sorghum.[a]

Cultivar	Grain color	Hardness (kg/cm^2) Whole grain	Dehulled grain	Cooking time (min)	% volume increase	% weight increase	Gruel solids (g/100 ml)	Overall acceptability[b]
M35-1	Pale yellow	7.7	1.9	41	288	170	1.08	1.6
GPR-148	White	8.5	2.8	36	350	184	0.65	2.7
P-721	White with brown spots	6.1	3.5	37	388	164	1.04	3.0
Market-1 (Hyderabad)	Yellow	6.9	3.5	39	370	176	1.11	2.8
CSH-1	Pale yellow	6.6	3.4	42	225	132	0.49	2.7
Swarna	Pale yellow	6.4	2.4	39	400	186	1.3	2.3
Local white	Pale yellow	5.6	2.6	33	363	164	1.00	2.5
SPV-351	Pale yellow	8.1	3.9	37	338	170	0.61	2.5
NK-300	Brown	6.5	4.7	39	300	124	0.61	3.9
CSH-8	Pale yellow	5.8	2.5	40	300	148	1.21	2.3
Market-2 (Hyderabad)	Pale yellow	7.6	2.0	37	400	174	1.53	1.3
IS-158 (Waxy)	Pale yellow	6.0	4.0	35	150	150	0.37	3.5
Mean		6.8	3.1	38	328	162	0.92	2.6
S.E.[c]		±0.72	±0.32	±1.0	±13.2	±6.4	±0.068	±0.40

a. Five g dehulled grains were cooked with 100 ml water over a hot plate, maintained at 350° C.

b. Evaluated by three panelists for appearance, softness, and acceptability on a scale of 1-5, where 1 is more acceptable. All values are a mean of at least two independent determinations; hardness is a mean of values from 20 individual grains.

c. Standard error of estimation.

following the method of Adkins and Greenwood (1966). Swelling power and solubility of the starch at different temperatures were determined as per Schoch (1964). Gelatinization of starch was measured by the Congo red method (MacMasters 1964). Inherent viscosity of the starch solution in sodium hydroxide at 25° C was determined using the Cannon-Ubbelohde viscometer (Myers and Smith 1964). Starch granule size was measured using a microscope. The variation for starch content in grain was between 62 and 72% (Table 4). Swelling power and solubility of starches were measured at 25°, 50°, 60°, 70°, 80°, and 90° C. Swelling power of starch at 25° C showed little variation, while the variation was large at 60° C being 1.1 to 7.5. The waxy cultivar (IS-158) showed greater swelling power at 90° C than other cultivars. The variation for solubility of starch ranged from 0.3 to 1.1, 0.9 to 5.7, and 7.0 to 18.0% at 25°, 60° and 80° C respectively. The gelatinization temperature of starch from the 12 cultivars ranged between 66.0 and 70.5° C. The variation for inherent viscosity and granule size of starch among the cultivars was limited.

Correlations among Cooking and Starch Properties

The relationship between cooking quality of boiled sorghum and starch characteristics has been studied and a few of the important correlations are given in Table 5. The volume increase of cooked grain was positively associated with percent increase in weight and gruel solids (Table 5). A negative relationship was observed between cooking time and volume increase. Grains having lower hardness values produced an acceptable product (r = 0.89). Of the several starch characteristics tested, only swelling power and solubility have shown a significant relationship with cooking quality of boiled sorghum. Percent weight increase of the product showed a negative relationship with starch solubility at 60° C, the temperature at which most of the starch granules reach gelatinization. Gruel solids showed a positive relationship with starch content in the grain.

Table 4. Starch characteristics of 12 sorghum cultivars.

Cultivar	Starch in dehulled grain (%)	Swelling power[a]			Starch solubility (%)[a]			BEPT[b] (°C)	Inherent viscosity (n)	Granule[a] size (μ)
		at 25° C	at 60° C	at 90° C	at 25° C	at 60° C	at 90° C			
M35-1	69.9	0.9	2.6	11.6	0.3	3.4	16.7	66.0	1.69	15.7
GPR-148	69.8	1.2	4.5	17.5	1.0	2.9	18.8	68.5	1.76	14.0
P-721	68.6	1.0	2.1	13.4	0.5	3.3	16.5	69.0	1.78	13.6
Market (yellow)	67.4	1.0	1.3	15.5	0.3	1.1	18.4	68.0	1.7	14.0
CSH-1	67.7	1.1	3.8	16.6	0.5	3.5	20.8	69.5	1.74	13.6
Swarna	71.8	1.1	3.8	16.6	0.5	2.9	20.9	70.5	1.76	12.3
Local white	69.5	1.1	3.0	15.1	0.8	2.5	21.6	70.0	1.71	12.6
SPV-351	66.6	1.0	4.9	18.8	1.0	2.1	22.5	68.5	1.76	12.9
NK-300	62.2	0.9	7.5	16.7	1.1	5.7	16.3	66.5	1.62	13.4
CSH-8	66.3	1.2	2.8	11.6	0.3	3.5	16.7	66.0	1.75	11.5
Market (white)	71.2	1.1	1.1	12.5	0.5	1.2	14.5	68.5	1.84	12.6
IS-158 (waxy line)	69.4	1.3	1.7	47.8	0.3	0.9	17.0	67.0	1.72	11.1
Mean	68.4	1.1	3.3	17.8	0.6	2.8	18.4	68.2	1.74	13.1
S.E. ±	2.36	0.03	0.47	0.62	0.02	0.21	0.60	0.63	0.037	2.08

a. Determined using isolated starch.

b. BEPT: Birefringence end point temperature (gelatinization temperature).

Table 5. Correlation coefficients (r) among the starch characteristics and cooking quality of boiled sorghum.[a]

Characteristics	(r)
% volume increase vs % weight increase	0.72*
vs gruel solids	0.62*
vs cooking time	−0.64*
% weight increase vs gruel solids	0.48
vs cooking time	−0.40
vs starch solubility at 60°C	−0.71*
Cooking time vs starch solubility at 60°C	0.32
Gruel solids vs starch content in grain	0.62*
vs grain hardness	−0.68*
vs swelling power of starch at 60°C	−0.72*
vs swelling power of starch at 90°C	−0.69*
vs solubility of starch at 25°C	−0.64*
vs solubility of starch at 50°C	−0.70*
Acceptability vs gruel solids	−0.65*
vs swelling power of starch at 60°C	0.67*
vs grain hardness	0.89*

a. based on 11 cultivars (waxy line IS-158 was not considered).
* Significant at 5% level; ** Significant at 1% level.

The swelling power of starch at 60° and 90° C and solubility at 25° C and 50° C showed a negative relationship with the gruel solids content. This may be due to the association of starch with factors like protein in the grain. Gelatinization temperature did not show a significant correlation with the cooking quality of boiled sorghum. But in rice, varieties with a high protein content and gelatinization temperature required longer time for cooking (Juliano 1972).

Our studies indicate that it is necessary to intensify research on the physical and chemical characteristics of starch to elucidate factors responsible for boiled sorghum quality.

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Sorghum *Couscous*: Quality Considerations

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Summary

Couscous *is the major sorghum food of the Sahelian zone of West Africa. With the exception of varieties with a thick testa or waxy endosperm, most sorghums can be prepared into acceptable* couscous. *In Mali, the most important* couscous *quality criterion is the yield of the final product compared with the original flour. There are large varietal differences for* couscous *yield that can be detected with the 20-g sample laboratory test described in this paper.*

Couscous is a steamed granulated product made from cereal flour. It is the principal cereal food of North Africa, the Sahara, and the Sahel. In North Africa and in the Niger inland delta, *couscous* is prepared from wheat, whereas in the Sahel it is prepared from pearl millet or sorghum. *Couscous* can be prepared directly into a steamed product that is eaten with a sauce. It can be steamed, sun dried, stored indefinitely, and reconstituted in milk, or again steamed and served with a sauce. The versatility of *couscous* preparation and storage serves well the migrant life style of Saharan and Sahelian pastoralists and seasonal farmers.

Preparation

Whole or dehulled grain is reduced to flour, which is sifted through a sieve with 1-mm mesh openings. Only the flour that passes through that sieve is used for *couscous* preparation.

The flour is wetted with cool water and agglomerated into small particles with the fingers. Those flour aggregates are forced through a sieve with 1.5-mm mesh openings. The wet aggregates are steamed in a covered perforated pot, which is placed directly over another pot containing boiling water. The juncture between the two pots is sealed with a damp cloth to force the steam through the perforations and into the flour aggregates. The wet cloth is wiped with okra (*Abelmoscus esculentus*) powder to assure a tight seal. In the absence of a cloth, a mixture of mud and okra powder is used to seal the two pots.

After about 15-min steaming, the aggregates form a large single chunk, which is taken out of the bowl, broken up into aggregates, and again steamed for an additional 15 min. The aggregates are again broken up into single units and sifted through a 2.5-mm sieve. At that point, the steamed aggregates can be dried and stored for future use. If *couscous* is to be consumed immediately, the aggregates are sprinkled with cool water and mixed thoroughly with the fingers. Baobab (*Adansonia digitata*) leaf powder is mixed with the particles. This powder serves as a lubricant, which prevents desiccation and stickiness, and improves palatability. Okra powder can be used as a substitute for baobab leaf powder. After mixing, the aggregates are again placed in the perforated bowl and steamed for about 15 min. The *couscous* is allowed to cool slowly and is then served with a sauce.

Couscous preparation is summarized in the diagram shown in Figure 1.

Quality Criteria

Couscous can be prepared from practically any cereal species and variety type within species. In Mali, a wide range of sorghum types is tolerated

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