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Properties of Sorghum Grain and their Relationship to *Roti* Quality

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Summary

Physicochemical characteristics of 45 sorghum genotypes were determined. The 100-grain weight, grain hardness, protein, water soluble protein, amylose, and sugars contents in the grain showed considerable variation. The roti *quality of flour from the 45 genotypes was evaluated for color, appearance, taste, flavor, and texture by a trained taste panel. The texture of dough was measured using an Instron machine. Relationships between the physicochemical characteristics of grain and* roti *qualities were identified. The quantity of water soluble protein, amylose, and sugars jointly influenced the* roti *quality of the sorghum genotypes studied.*

Sorghum grains are used as the staple food in several regions of Africa, China, and the Indian subcontinent particularly in the semi-arid tropics. It has been well established that chemical components such as protein, starch, lipids, and ash of wheat flour influence the breadmaking quality (Pomeranz et al. 1979). Studies on rice (Juliano 1979) indicated the importance of amylose and protein on the cooking and eating quality of rice. Physicochemical characteristics of sorghum and their effect on sorghum food products have not been well documented. Miller and Burns (1970) studied the relationship between the starch characteristics and organoleptic qualities of sorghum bread and reported that varieties with high amylopectin content were preferred for sorghum bread. However, Miche et al. (1976) indicated that the role of lipids during pasta manufacture and the role of amylose, amylopectin of sorghum starch, and other protein fractions had not been investigated. The role played by chemical or physical factors of sorghum grain on food quality appears to be a complex phenomenon. Our work on *roti* evaluation (Subramanian and Jambunathan 1980) revealed that physicochemical factors jointly influence the *roti* quality of sorghum. In this paper the properties of sorghum flour and their relationship to *roti*(*chapati*) quality from 45 cultivars are discussed.

Materials and Methods

Physical Properties

Forty-five sorghum cultivars of varying grain characteristics (Table 1), grown at ICRISAT Center during the postrainy seasons of 1979 under uniform field conditions, were studied. Grain hardness (kg/cm^2) was measured as the force required to break the grain using a Kiya hardness tester. Whole grains were ground to flour in a UDY Cyclone Mill to pass through a 60-mesh sieve. The flour was defatted using n-hexane for further analysis. The swelling capacity of flour was determined by treating 0.5 g flour in 15 ml water and the contents were kept in a heating block maintained at 90° C for 1 hr. The volume and weight increase of flour were determined and expressed as the ratio between initial volume and final volume (v/v) or weight (v/w). The solute content of the water extract of flour at 90° C, designated as the water soluble flour fraction (WSFF), was determined as follows. A quantity of flour, 0.5 g, was heated with 15 ml water for 1 hr at 90° C with periodical shaking. The contents were cooled and centrifuged. The supernatant was made up to 50 ml. An aliquot was evaporated to dryness and the weight of the dissolved solids was designated as WSFF.

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content should be confirmed by isolation of the starch.

It appears that both environment and genetic factors affect the level of amylose in nonwaxy sorghums. However, significant heritable differences in amylose content have not been clearly demonstrated in nonwaxy sorghums.

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Table 1. Grain characteristics of 45 sorghum cultivars.

Cultivar	Grain color	Corneousness[a]	Grain hardness (kg cm^{2})	100-seed weight (g)
PJ-7R	White with red spots	3	6.4	4.32
PJ-16R	Creamy white	3	6.0	3.90
PJ-18R	Light yellow	3	6.3	4.04
PJ-19R	White with brown spots	3	6.6	4.14
PJ-1K	White with red spots	3	6.0	4.44
PJ-2K	White with red spots	4	5.6	4.68
PJ-4K	White with red spots	4	6.3	4.65
PJ-12K	Creamy white	4	6.4	5.45
PJ-14K	Creamy white	3	6.3	2.77
PJ-31K	Creamy white	4	6.1	4.65
PJ-32K	Creamy white	4	6.8	4.88
Maldandi local	Creamy white	4	7.3	3.93
Karad local	Creamy white	3	6.8	3.70
SS-2	White with brown spots	3	6.7	3.53
Pickett-3	White with red spot	3	8.2	3.31
GM-2086	Light brown	4	6.6	4.05
[illegible]imila	Light brown with subcoat	4	7.2	2.65
NJ-1346	Creamy white with brown spots	2	8.3	3.38
NJ-1953	Creamy white	4	7.9	4.53
Dholio	White with brown spots	4	5.2	5.01
Surat-1	Creamy white	4	5.9	4.49
Aispuri	Dull white	4	5.0	3.57
K. white grain	White with brown spots	3	7.2	3.57
Vidisha 60-1	Dull white	4	5.4	4.26
BP-53	Dull white	4	7.0	4.60
FR-178	White with brown spots	3	6.1	3.19
H-102	Creamy white	3	6.0	3.61
H-107	White with brown spots	3	6.7	3.54
SPV-35	White with red spots	3	7.8	3.38
S-302	White with red spots	3	7.8	4.11
269	Creamy white	3	7.9	3.27
285	Creamy white	3	6.5	3.01
296	Dull white	4	6.7	4.09
370	Creamy white	3	7.4	3.13
1235	Creamy white	3	7.5	2.75
[illegible]S-12611	Dull white	3	11.8	4.24
E-12-5	Creamy white	2	11.8	3.36
E-35-1	White	2	6.7	3.54
Bodgawanda-wani	White with pink spots	4	6.6	3.88
Mau-wani	White with pink spots	5	3.0	2.65
Vani-Wani	White with pink spots	4	5.2	3.20
Naraliguti Wani	White with pink spots	4	6.1	3.77
Pandori-Wani	Creamy white	5	4.9	2.30
Bilora-Wani	Creamy white	4	7.3	4.57
Lahi-Wani	White	3	5.6	4.22

a. Corneousness was measured on a scale of 1–5, where 1 is more corneous and 5 is floury.

Chemical Characteristics

Protein was determined by the microKjeldahl method (AOAC 1970). Water soluble protein of flour was extracted by shaking 1 g flour in 15 ml water at room temperature. The extraction was repeated with 10 ml water and the extracts were combined and made to 50 ml. A 10 ml aliquot was treated with trichloroacetic acid (TCA) to yield a final concentration of 10%. The resulting precipitate was dissolved in 1 ml of 0.1 N NaOH and the protein content was determined by the method of Lowry et al. (1951). The amino acid composition was determined using Beckman (120-C) amino acid analyzer. Starch content was estimated using the enzyme glucoamylase as reported by Singh et al (1980). Total amylose was determined according to Williams et al. (1958); water soluble amylose was estimated colorimetrically (Juliano et al. 1968). Total sugars were determined by the phenol-sulphuric acid method (Dubois et al. 1956) and the reducing sugars by using Nelson Somogyi reagent (Somogyi 1952). Fat and ash contents were analyzed by the AOAC (1970) methods. For gel filtration chromatography of the water soluble protein, a solution containing 5 mg protein was applied on a Sephadex G.100 column (82 × 1.5 cm). The protein was eluted using 0.01 M phosphate buffer (pH 7.6) containing 0.01 M mercaptoethanol, 0.4 M sodium chloride and 0.05% sodium azide. Absorbance of the eluent was recorded by a LKB 8300 UVCORD monitor.

Dough and *Roti* evaluation

Dough quality was evaluated subjectively for kneading and rolling qualities. Dough stickiness was evaluated using an Instron machine. Dough was prepared by mixing 50 g flour with 40 ml water. After kneading well, the contents were divided into three equal parts by weight. The dough was placed in the back extrusion cell of the Instron machine (Model 1140) and compression was made. The force required for back extrusion, area and slope of the curve were determined from the recorded tracings.

Rotis were made as per the procedure outlined by Subramanian and Jambunathan (1981). The organoleptic properties such as color and appearance, flavor, taste, texture, and general acceptability were evaluated with a trained taste panel consisting of 12 persons.

Results and Discussion

Physicochemical Characteristics

The grain hardness showed a wide variation of 3 to 12 kg (Table 1). The range and mean values of physicochemical characteristics of sorghum flour are given in Table 2. Swelling capacity of flour varied from 5 to 8 on a volume basis. The WSFF ranged from 19 to 35 mg/100 g. The protein content of the 45 cultivars varied from 8 to 14%. The protein content in the water soluble fraction of the flour ranged from 0.3 to 0.9% of grain. Gel filtration of water soluble proteins on Sephadex G-100 in phosphate buffer at pH 7.6 yielded two major peaks (Fig. 1). Though variation was observed for the amino acid composition of the water soluble fraction of the two cultivars (Table 3), further studies are needed to draw proper conclusions.

Starch is the major constituent of sorghum grains. The role of starch in the breadmaking quality of wheat is well known due to its effect on water absorption (Alsberg 1927). The starch content of the grain of the 45 sorghum cultivars varied from 62.6 to 73.3% and the amylose content ranged between 21.2 and 30.2% (Table 2). Hulse et al. (1980) reported that the amylose content in 100 sorghum lines ranged from 7.1 to 31.3%. Waxy sorghums are reported to have a low amylose content. The water soluble amylose of the 45 cultivars ranged from 4.8 to 12.7% of the grain. Sorghum grains contain five different sugars, i.e., sucrose, stachyose, raffinose, glucose, and fructose in varying proportions (Subramanian et al. 1980). The fat content in sorghum samples varied from 2.3 to 4.7% and ash from 1.3 to 2.2% (Table 2).

Relationship among the Physicochemical Characteristics

The relationship among the physicochemical characteristics of sorghum grain has been worked out and some are given in Table 4. The 100 grain weight showed a negative association with protein while it was positive with amylose. Swelling capacity of flour was not associated with any of the chemical factors. Protein content showed a strong negative relationship with starch and water soluble amylose contents in the grain and was positively related with water soluble protein, and

Table 2. Physicochemical properties of sorghum grain.[a]

	Range	Mean	± s.e
Physical characteristics			
Flour swelling capacity (v w)	8.7-12.8	10.4	0.30
Flour swelling capaçity (v v)	5.4-8.0	6.5	0.19
WSFF (mg 100 g)[b]	19.4-35.4	26.4	0.86
Chemical characteristics (percent in grain)			
Protein	8.0-14.1	10.6	0.10
Water soluble protein	0.3-0.9	0.6	0.009
Starch	62.6-73.3	68.7	2.36
Total amylose	21.2-30.2	27.2	0.88
Water soluble amylose	4.8-12.7	8.5	0.20
Soluble sugars	0.7-1.6	1.0	0.03
Reducing sugars	0.05-0.4	0.1	0.004
Fat	2.3-4.7	3.3	0.06
Ash	1.3-2.2	1.6	0.01

a. based on 45 cultivars.
b. Water soluble flour fraction.

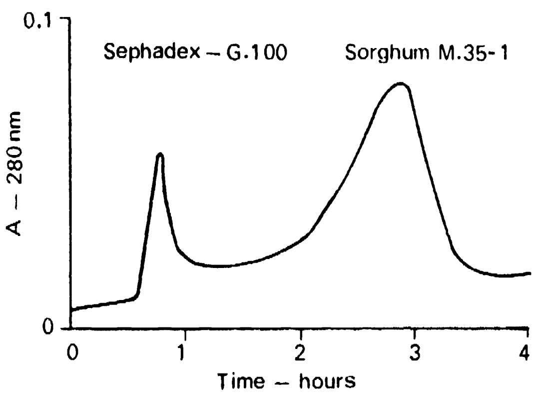

Figure 1. Gel filtration elution profile of water-soluble proteins.

ash contents. The starch content was positively associated with water soluble amylose. Miller and Burns (1970) observed that amylose content was directly related to starch content in sorghum. Soluble sugars content showed a positive correlation with protein and a negative correlation with amylose.

Table 3. Amino acid composition of the water soluble fraction (g/100 g protein).

	Cultivars	
Amino acids	PJ. 12-K	IS-12611
Lysine	6.77	8.42
Histidine	2.01	2.43
Arginine	5.08	6.17
Aspartic acid	8.38	9.39
Threonine	4.04	4.45
Serine	3.60	3.85
Glutamic acid	12.16	14.77
Proline	7.44	5.53
Glycine	5.38	6.21
Alanine	6.46	7.13
Half cystine	Tr	0.67
Valine	6.03	6.82
Methionine	1.00	1.57
Isoleucine	3.19	3.06
Leucine	5.57	6.45
Tyrosine	2.41	2.90
Phenylalanine	2.79	3.54
Total	82.31	93.36

Dough Quality

Although sorghum grains do not contain gluten, when sorghum flour is mixed with water and kneaded, it produces a sticky dough. A good quality dough should be sticky and easily rollable into a *roti* without any breakage. The stickiness of good and poor doughs was measured using an Instron machine and the profiles are shown in Figures 2a and 2b. A sticky dough yields a profile requiring less force for deformation but has a steep slope. A poor dough becomes compressed in the cell and is not extruded back; consequently, the force required for compression increases. The slope is comparatively steady and higher for cultivars like IS-12611 and M-35-1 having good dough characteristics (Table 5).

Table 4. Correlations (r) among physicochemical characteristics of sorghum grain.

Characteristics	Protein	Water soluble protein	Amylose	Water soluble amylose
100-grain weight	−0.44**	−0.44**	0.33**	0.70**
Flour swelling capacity	−0.27	0.14	−0.04	0.07
WSFF[a]	−0.25	−0.25	0.16	0.38*
Protein	1.00	0.40**	−0.27	−0.66**
Water soluble potein	0.40**	1.00	0.12	0.41**
Starch	−0.75**	−0.49**	0.22	0.74**
Amylose	−0.27	−0.12	1.00	0.36**
Water soluble amylose	−0.66**	−0.41**	0.36*	1.00
Soluble sugars	0.36*	0.51**	−0.52**	−0.55**
Reducing sugars	0.25	0.18	−0.53**	−0.37**
Ash	0.46**	0.60**	−0.44**	−0.52**

n = 45; * Significant at 5% level. ** Significant at 1% level.
a. Water soluble flour fraction.

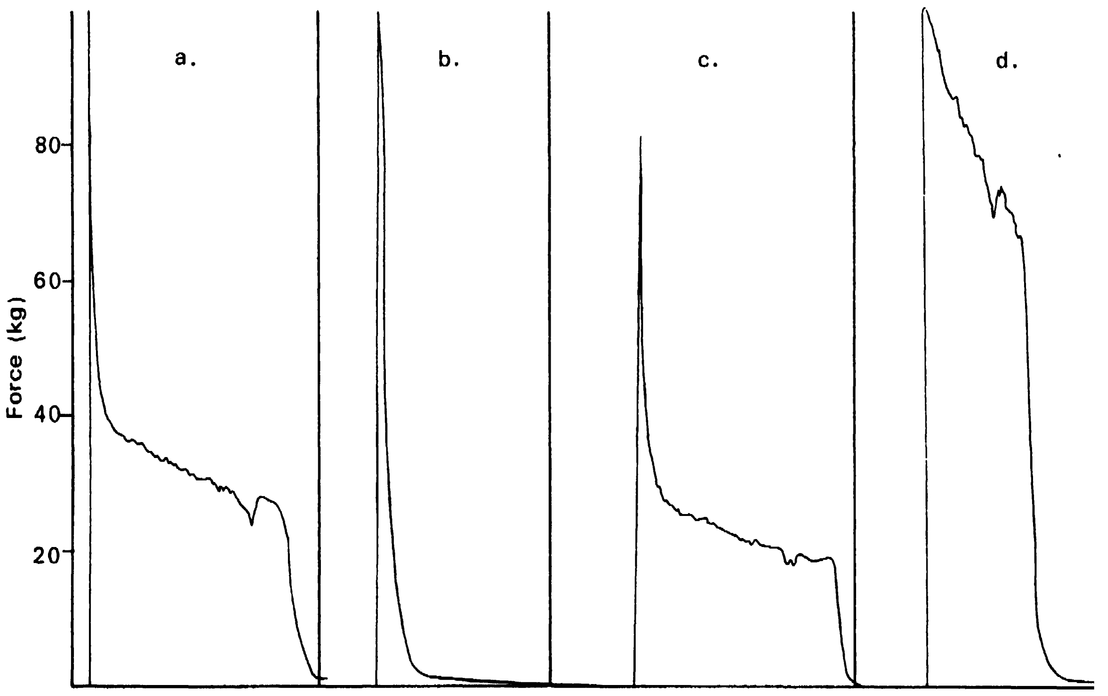

Figure 2. Force-distance curves of sorghum dough (Back extrusion—Instron). Dough was prepared by mixing 50 g flour with 40 ml water or water extract of flour. a: IS. 12611 flour + water; b: Simila flour + water; c: IS. 12611 flour + water extract of Simila flour, and d: Simila flour + water extract of IS. 12611 flour.

Our preliminary experiments showed that water extracts of sorghum flour (water solubles) influenced the dough stickiness. Studies were made with two cultivars possessing good and poor dough stickiness. The flour of IS-12611 yielded a good sticky dough and that of Simila yielded a dough with less stickiness. The flour samples were each extracted with water. The water extract obtained from Simila flour was added to the flour of IS-12611 to make the dough. However, this did not alter the dough characteristics appreciably as shown in Figure 2c. On the other hand, when the water extract from IS-12611 flour was added to Simila flour to make the dough, the stickiness of the dough was improved considerably as shown in Figure 2d. This indicates that water soluble components play an important role in the quality of dough and there is a need to characterize the nature of these components.

Relationship between *Roti* Quality and Physicochemical Characteristics

The association between the physicochemical characteristics and the taste panel score was studied. Pomeranz (1980) indicated that the problems of relating chemical composition and structure of wheat flour components to functional properties in breadmaking were complicated by several factors. Our earlier studies indicated that the physical factor WSFF and the chemical factors, i.e., water soluble amylose, sugars and ash contents jointly influenced the *roti* quality (Subramanian and Jambunathan 1980). A comparison of the mean values of WSFF, water soluble protein, and total amylose contents in flour for some cultivars having poor and good *roti* qualities is presented in Table 6. The flour samples having a lower amount of WSFF and higher amounts of water soluble protein and total amylose produced good *rotis*. The earlier studies with 25 cultivars involving samples from the International Sorghum Food Quality Trials (Murty and House 1980) indicated that amylose percent in grain was positively associated with overall *roti* and *tô* qualities.

With the objective to study the relative contribution of the flour components to *roti* quality, stepwise multiple regression was adopted by considering *roti* quality characters as dependent variables and the physicochemical characters as independent variables. The results are given in Table 7. The color and appearance of *roti* showed a positive relationship with water soluble protein and total amylose, and negative relationships with starch and reducing sugars. The texture of *roti* showed strong relationships with protein and total amylose, and a negative association with soluble sugars. Taste was inversely related to reducing sugars, WSFF and flour swelling capacity, while a positive relationship was observed with water soluble protein. Flavor also showed a positive relationship with protein, amylose and ash contents. The joint effect of flour components on *roti* quality needs to be studied in detail. This would assist in developing a rapid screening methodology that could be used for testing early

Table 5. Textural characteristics of dough from eight sorghum cultivars measured with a back extrusion cell in an Instron machine.

Cultivar	Rolling quality[a] (cm)	Kneading quality[b] (score)	First point[c] (kg)	Yield point[c] (kg)	Work done[c] (sq cm)	Slope[c]
Simila	14	3	(a single peak—no extrusion)			
P-721	16	3	"			
PJ-12-K	22	3	12.5	20.0	10.8	0.25
Karad local	22	2	19.3	25.7	15.3	0.24
269	24	1	27.5	39.0	24.1	0.40
IS-12611	24	1	35.0	48.8	28.4	0.49
IS-1235	23	1	43.3	53.7	32.4	0.40
M-35-1	24	1	41.8	58.0	34.3	0.60

a. Rolling quality was measured as the maximum diameter rollable into *roti* from dough made from 50 g flour.
b. Kneading quality was scored subjectively over a scale of 1 to 3, where 1 is good and 3 is poor.
c. Values recorded from Instron machine using a back extrusion cell.

Table 6. Comparison of physicochemical characters of sorghum cultivars having poor and good *roti* qualities.

Cultivar	Grain color	Mean *roti* quality score[a]	WSFF[b] (mg/100 g)	Water soluble protein in whole flour (%)	Total amylose in whole flour (%)
Poor *roti* types					
PJ-16R	Creamy white	1.5	29.8	0.30	25.1
PJ-19R	White with brown spots	1.8	28.9	0.44	24.8
PJ-2K	White with red spots	1.9	33.9	0.34	27.1
Simila	Light brown	1.7	26.6	0.63	21.5
Mau-Wani	White	1.9	35.0	0.62	22.2
Mean ± SD		1.8 ± 0.15	30.8 ± 3.15	0.47 ± 0.14	24.1 ± 2.04
Good *roti* types					
285	Creamy white	3.1	26.3	0.60	29.9
E-35-1	Creamy white	3.1	19.4	0.71	29.9
IS-12611	Dull white	3.3	24.7	0.58	28.8
Bodgawanda Wani	White with brown spots	3.1	22.0	0.60	28.0
Vidhisha 60-1	Dull white	3.0	29.2	0.85	28.2
M-35-1 (Check)	Creamy white	3.3	21.0	0.80	28.2
Mean ± SD		3.2 ± 0.11	23.8 ± 3.33	0.69 ± 0.11	28.8 ± 0.79

a. Average evaluation scores of taste panel for color, appearance, texture, taste, flavor, and acceptability, (Score 4 = good; 1 = poor).
b. Water soluble flour fraction.

generation materials in a breeding program.

Acknowledgments

The authors thank K. E. Prasada Rao for kindly providing the samples and C. D. Ramaiah and K. A. R. Zafar for their technical assistance.

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Table 7. **Stepwise multiple regression coefficients for the physicochemical characters and *roti* quality of sorghum grain.**

	Regression coefficient	Computed T	R^2	Level of significance
Roti color and appearance				
Grain hardness	0.18	3.54	0.65	**
Water soluble protein	1.34	2.65		*
Reducing sugars	−6.28	−4.79		**
Starch	−0.12	−3.40		**
Roti texture				
Protein	0.19	3.73	0.62	**
Total amylose	0.10	3.20		**
Water soluble protein	1.23	2.39		*
Soluble sugars	−1.69	−3.23		**
Ash	1.30	2.57		*
Roti taste				
Water soluble protein	1.26	2.90	0.62	*
Reducing sugars	−2.28	−2.28		*
Flour swelling capacity	−0.19	−2.00		*
WSFF[a]	−0.02	1.55		+
Roti flavor				
Protein	0.11	3.05	0.41	**
Total amylose	0.07	3.32		**
Ash	0.61	2.20		*
Fat	−0.16	−1.55		+
General acceptability				
Water soluble protein	0.81	2.42	0.48	*
Reducing sugars	−3.46	−4.12		**
Protein	0.10	2.41		*
WSFF	−0.23	−1.83		+

a. WSFF: Water soluble flour fraction.
** Significant at 1%
* Significant at 5%
+ Significant at 10%

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