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EVALUATION OF SORGHUM GRAIN QUALITY AS INFLUENCED BY MILLING METHODS[1]

ABSTRACT

Grain samples from twelve sorghum cultivars representing a wide range of hardness were milled by using three different milling systems: village *chakki*, laboratory carborundum mill and Udy cyclone mill. The flour samples were studied for their particle size (% < 75 mu), percent starch damage, percent water retention capacity, volume of water required to make dough (ml), rolling quality (cm), gel spread (mm), and dough extrusion foce (kg) in an Instron Food Testing Machine. The *chakki* milled flour showed significantly larger particle size but superior rolling quality. Starch damage, water retention capacity, rolling quality and gel spread values of the chakki and laboratory milled flour samples were higher and were in the same range, inspite of significant cultivar x mill effects. The Udy mill flour showed the least amounts of starch damage and water retention and poor rolling quality. Variation in dough rolling quality was largely affected by milling method while that of gel spread was influenced by cultivars. Significant correlations were observed between grain hardness and quality parameters of flour from *chakki* and Udy mills, indicating an interaction of milling methods with grain hardness. Rolling quality of the dough was positively correlated with percent starch damage and water retention capacity and negatively associated with extrusion force.

INTRODUCTION

Sorghum (*Sorghum bicolor* L. Moench) grain is consumed in India, Africa and Central America as a staple food in the form of several traditional recipes prepared by following an array of processing methods (Vogel and Graham, 1979). Murty and Subramanian (1982) and Murty et al (1982a) estimated that approximately 70 % of the sorghum produced in India is consumed in the form of *roti* (unleavened bread) while 15 to 20 % is eaten as a thick porridge (neutral pH) called *sankati* or *mudde*. They reviewed the traditional methods of preparation and quality parameters of these foods. *Roti* is prepared from a dough obtained by using whole grain flour milled in a village *chakki* (power driven stone mill). Traditionally, dehulled grains have been used for preparing *sankati*. However, in recent years this practice has been given up and grits or coarse flour from whole grains milled in *chakki* are being used for preparing *sankati*. Apparently, these milling methods result in the production of the food recipes of acceptable quality. However, there is no information on the specific effects of the milling methods on product quality. It is also not known whether other milling methods available can yield products of similar quality. Such information would be useful in finding out suitable laboratory and industrial processing methods.

Significant variation in the quality of *roti* and *sankati* were reported among cultivars (Murty et al. 1982a, b). Sorghum grains with a white or colorless pericarp and free from testa are preferred for use in *roti* and *sankati* preparation. Grains with 60 to 70 % corneous endosperm produced superior quality *roti* while grains with 60 % corneous endosperm texture suited for producing a good quality *sankati*. It was also found that *roti* quality was highly associated with dough rolling quality and that viscosity and keeping quality of thick porridges were associated with gel spread (Murty et al. 1982b, c). An understanding of physicochemical factors governing product quality would help in devising simple and rapid tests that enable breeders to evaluate large number of breeding progenies for their food quality. The objectives of the studies reported here are: (i) to investigate the effect of different milling equipments on the flour and dough quality parameters and (ii) to identify the flour quality components that are closely associated with *roti* dough and porridge quality.

MATERIALS AND METHODS

Grain samples of twelve sorghum cultivars of varied endosperm texture were chosen for the present studies. All of these have a colorless or white pericarp and no testa (see Table 1 for details). These cultivars were grown at the ICRISAT Center during the season of September-December 1982 under uniform irrigated field conditions. Grain harvests were dried to a 10 ± 1 % moisture content and stored in plastic bottles for further use.

I. Proximate Analyses:

Grain samples were ground in a Udy cyclone mill provided with a 0.4 mm screen and were defatted in Soxhlet apparatus for six hr using n-hexane. The Technicon auto analyser procedure was employed to determine nitrogen content (Singh and Jambunathan, 1980). Nitrogen content was converted into percent protein by multiplying with a factor of 6.25. Ash, crude fiber and fat content were determined according to the procedures of Association of Official Analytical Chemists

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Table 1: Proximate composition of sorghum grains (%)

Cultivars	Floaters (%)	Pearling Index	Protein	Starch	sugars	Fat	Crude fibre	Ash
E 35-1	12	86.4	10.8	65.9	1.27	2.66	1.99	1.36
S 29	9	86.0	12.4	68.0	1.11	3.20	1.45	1.38
IS 12611	16	84.0	10.8	64.2	1.18	2.60	1.98	1.32
SPH 265	3	85.6	10.5	66.5	1.28	3.40	1.96	1.38
Tetron	56	80.3	12.8	69.0	1.37	3.62	1.30	1.58
Safra	63	77.2	9.8	68.9	1.25	2.58	2.40	1.33
SPH 225	42	69.7	10.5	68.0	1.63	2.92	2.13	1.29
SPV 475	28	79.4	9.3	69.5	1.51	2.82	1.87	1.34
M 35-1	9	82.6	9.7	69.5	0.99	2.58	1.54	1.40
ET 3491	46	60.3	11.5	66.6	1.20	3.10	1.99	1.54
E 187	69	65.6	12.4	67.8	1.18	2.82	1.65	1.62
P 721	90	62.2	13.3	62.8	1.86	3.66	2.04	1.91
Mean	36.9	76.6	11.2	67.2	1.32	3.00	1.86	1.45
SE ±	3.0	1.35	0.36	0.58	0.07	0.11	0.09	0.05

(AOAC 1975). Soluble sugars and starch were estimated according to the method described by Singh et al (1981).

II. Grain Hardness Evaluation:

Hardness of the grain samples was evaluated by two different methods.

a) Percent grains floating in a solution of sodium nitrate (1.3 s.g) were estimated in 3 independent samples of 300 grains each for all the cultivars (Hallgren and Murty, 1983).

b) Percent grain recovered after pearling 20 g sample of grain (>1700 u, % pearling index) in a Forsberg Seed Scarifier (Forsberg Inc., Minnesota) for 45 sec. Three independent observations were made on each cultivar.

III. Milling methods:

Three different milling equipments were used to obtain whole grain flour: (i) A *chakki* equipped with two red stones placed on a horizontal axis and driven by an electric motor (10 H.P., Bemco-16 Bemco Agro Implements P. Ltd., Belgaum, India). The *chakki* was located in a village (Ramachandrapuram) near ICRISAT Center. (ii) A Laboratory carborundum stone mill (Milcent, Size D-2, Balaji Mill Traders, Secunderabad, India) with two stones on a vertical axis and powered by a 5 HP motor, and (iii) A Udy cyclone mill. The *chakki* and laboratory mills were operated at a constant speed and setting. The clearance between stones was adjusted to the specific range that sorghum consumers generally prefer. In the case of *chakki* which is difficult to clean, 3 kg lots of grain were ground and the middle portion of 1 kg output was collected. One kg lots of grain were ground in the laboratory mill and before grinding each lot the mill was cleaned with an air blower. The Udy cyclone mill was operated with a 0.5 mm screen and normal cleaning precautions were taken after grinding 500 g of grain for each cultivar.

IV Flour Quality Parameters

a) Particle size was estimated by hand sieving a 25 g sample of flour with a US standard sieve (75 mu) until no more flour passed through. Two independent observations were made for each sample.

b) Rolling quality of the dough was estimated as per the procedures given by Murty and Subramanian (1982).

c) Gel spread of the porridge was estimated by using the methods of Murty et al. (1982c).

d) Percent starch damage.

The percent starch damage was estimated by using a-amylase enzyme according to the method of American Association of Cereal Chemists (AACC, 1969).

e) Percent Water Retention Capacity

Water retention capacity was estimated following the method outlined by Sollars (1972). Flour sample (5 g) was transferred into a weighed 50 ml centrifuge tube and 25 ml of distilled water was added. The tube was stoppered and shaken vigorously. The contents were allowed to stand for 20 min with shaking every five min. It was then centrifuged for 15 min at 1000 xg. The supernatant was decanted and the tube was drained at a 45 degree angle. The tube was weighed and the gain in weight was expressed as percent water retention capacity. Duplicate observations were made for each sample and averages were considered for the statistical analysis.

f) Extrusion Force:The methods followed for measuring the physical characteristics of dough using an Instron Food Testing Machine (Table Model 1140, High Wycombe, Berkshire, UK) provided with a back extrusion cell were described in detail by Subramanian et al. (1984). Distilled water was added in small increments to 50 g flour and the mixture was hand kneaded until appropriate consistency was obtained. Optimum dough consistency was judged subjectively. The quantity of water (ml) required for achieving desirable dough consistency was noted. The dough was divided into 3 equal parts by weight. The dough sample was introduced into the back extrusion cell and the initial force (kg) required for extrusion, commonly referred to as extrusion force, was obtained from the graph.

RESULTS AND DISCUSSION

The proximate analyses of grain samples of the 12 cultivars showed limited variation for protein, starch, soluble sugars, fat, ash and crude fibre contents with a

Table 2: Flour particle size, rolling quality and gel spread of twelve sorghum cultivars milled in three different methods

Cultivar	Flour<75 mu %			Rolling quality cm			Gel spread mm		
	V	L	U	V	L	U	V	L	U
E 35-1	36.8	43.7	44.9	23.5	21.8	20.0	55	56	56
S 29	34.4	39.1	45.6	24.5	23.8	21.5	58	58	57
IS 12611	36.3	49.0	46.2	24.9	22.3	18.8	59	63	58
SPH 265	41.7	43.7	[illegible]	23.9	24.3	20.0	57	57	56
Tetron	42.9	43.2	47.7	24.5	23.3	21.6	58	61	60
Safra	44.9	46.3	48.0	24.6	23.0	17.3	61	65	65
SPH 225	46.4	55.0	48.0	24.4	23.3	19.3	58	60	58
SPV 475	42.2	31.4	47.2	23.8	21.8	20.0	58	58	60
M 35-1	42.1	47.5	46.4	24.1	23.8	18.8	58	62	58
ET 3491	44.9	52.0	51.7	23.9	22.0	19.3	62	64	62
ET 187	47.5	60.3	51.2	22.9	22.3	16.6	62	62	59
P 721	59.1	67.3	58.7	18.8	20.0	14.1	76	77	67
Mean	43.3	48.1	48.0	23.6	22.6	18.9	60	62	59
Overall Mean ± se		46.4 ± 1.44			21.7 ± 0.35			60.4 ± 0.98	

Analysis of variance (MSS)

		d.f.	Flour<75 mu %	Rolling quality cm	Gel spread mm
Replications	(R)	1	0.2	2.3	0.1
Mills	(M)	2	184.4**	147.6**	36.2**
RxM		2	1.5	3.4	0.2
Cultivars	(C)	11	238.6**	13.2**	127.9**
RxC		11	1.6	0.1	0.5
MxC		22	35.2**	1.9**	7.5**
RxMxC		22	1.6	0.3	0.8

V = Village *chakki* L = Laboratory Carborundum Mill U = Udy Cyclone Mill
* Significant at 5 % probability ** Significant at 1 % probability

few exceptions (Table 1). The grain hardness parameter, % floaters varied from 3 to 90 and showed a broad range with a mean of 37 ± 3.0. Percent of the pearled product (pearling index) varied from 60.3 to 80.4 and confirmed the variation in the hardness of the 12 cultivars observed by estimating percent floaters. As expected percent floaters and pearling index were found to be highly correlated (r = -0.97, P = 0.01). Kirleis and Crosby (1982) and Hallgren and Murty (1983) suggested the use of floatation technique for routine grain hardness evaluation in quality breeding programs.

Observations on percent of flour passing through a 75 mu screen, rolling quality of the dough and gel spread are shown in Table 2. On an average, 48 % of the flour from the Udy and laboratory mills passed through the 75 mu screen while only 43 % of the flour from the *chakki* passed through. This indicates a significantly larger particle size of the flour from the *chakki*. However, rolling quality and gel spread of the *chakki* flour was as good or even better than that from the laboratory and Udy mills. The average rolling quality of the Udy mill flour was only 18.9 cm compared to about 23 cm of the *chakki* and laboratory flour samples. The range of rolling quality and gel spread values for the *chakki* and laboratory milled flour samples were comparable. However, rolling quality of several cultivars was significantly better when they were milled in the *chakki*. The flour from the laboratory mill produced a thinner gel (x = 62 mm). The property of producing a thick gel is a criterion for good quality porridges (Rooney and Murty, 1982). Significant variances were observed among cultivars, mills and cultivars x mills for flour particle size, rolling quality and gel spread (Table 2). Variation due to milling effects were the largest for rolling quality while cultivar effects contributed maximum variation for gel spread. Variation in flour particle size was equally affected by cultivars and mills. Therefore, predictions of food quality based on observations made using one milling system may not hold true with the products made using another milling system. It is important to choose the most appropriate milling system before investigating the quality of traditional foods.

Table 3 shows estimates for percent starch damage, percent water retention capacity, volume of water required to make dough and the initial force (kg) required for back extrusion of the dough. Percent starch damaged in the flour samples varied from 10.1 to 25.1 ($\bar{x}$ 19.9 ± 0.49). Udy mill samples exhibited a distinctly lower percent of starch damage ($\bar{x}$ = 15.3). The *chakki* flour and laboratory milled flour exhibited the same range of % starch damage. However, there were significant cultivar and cultivar x mill differences. A greater proportion of the variation in % starch damage was due to milling effects. Data on percent water retention capacity and the amount of water used to make dough for Udy milled flour samples was much lower than those observed for *chakki* and laboratory milled flour.

The Instron graph data showed that, on the average, the Udy milled flour required a much higher extrusion force for back extrusion of the dough (42.6 kg) than the

Table 3: Flour quality parameters of 12 sorghum cultivars milled by three ˙˙ᶠ˙ⁿent mer'

Cultivar	Starch damage %			Water retention capacity %			Initial force (kg) extrusion			Volume of water for dough (ml)		
	V	L	U	V	L	U	V	L	U	V	L	U
E 35-1	22.3	23.4	16.0	154	157	136	32	28	54	46	49	43
S 29	25.1	21.4	20.9	158	152	136	51	39	41	43	45	40
IS 12611	23.9	21.8	17.7	158	154	128	26	40	41	47	46	42
SPH 265	21.5	21.6	16.1	148	153	131	31	21	42	46	45	40
Tetron	22.9	21.6	16.2	147	144	125	24	26	19	45	45	40
Safra	21.6	20.4	15.6	157	143	124	19	30	40	47	46	41
SPH 225	21.1	21.2	16.0	151	160	135	36	27	43	46	47	41
SPV 475	24.0	22.5	18.6	157	144	131	29	37	48	46	43	41
M'35-1	24.4	23.2	13.8	146	151	121	25	34	40	44	46	40
ET 3491	21.1	24.8	12.1	149	147	113	30	29	32	43	44	40
ET 187	20.4	24.5	13.5	142	149	119	32	33	50	41	41	40
P 721	17.4	21.2	10.1	129	139	119	43	49	62	41	41	41
Mean	22.6	21.8	15.3	149.4	148.6	126.1	31.6	32.6	42.4	44.6	44.9	40.7
Overall mean ± se	19.9± 0.49			141.3± 1.44			35.9± 1.5			43.4± 1.5		

Analysis of variance (MSS)

	d.f.	Starch damage	Water retention capacity	Initial force	Volume of water
Replications (R)	1	2.0	0.3	53.4	
Mills (M)	2	381.5**	4201.2**	864.2*	64.19**
RxM	2	0.7	2.8	12.9	
Cultivars (C)	11	10.9**	204.6**	311.2**	7.27**
RxC	11	0.2	1.6	10.1	
MxC	22	11.9**	50.4**	89.1**	1.76
RxMxC	22	0.2	2.3	5.9	

V = Village *chakki* L = Laboratory Carborundum Mill U = Udy Cyclone Mill
* Significant at 5 % probability ** Significant at 1 % probability

chakki and laboratory milled flour. The range of the extrusion force required for Udy milled flour samples was also much wider (19–62 kg). The correlation between extrusion force and the rolling quality of the corresponding flour samples was found to be highly negative (r = -0.63, P = 0.01) suggesting that samples exhibiting good rolling quality require low extrusion force. These results bring out clearly the poor quality of dough produced by the Udy milled flour in contrast to the *chakki* and laboratory milled flour.

The flour samples exhibited a broad range of dough quality and provided an opportunity to investigate factors associated with rolling quality. An analysis of correlations among the flour and dough quality parameters showed (Table 4) that percent starch damage, water retention capacity and rolling quality of the flour were highly correlated (r = > 0.8). The parameter percent water rentention capacity was highly correlated with volume of water required and was probably a better measure of water absorption. Gel spread was observed to be highly correlated with particle size of the flour. Increased starch damage possibly leads to increased water retention and a better rolling quality. Milling systems which cause more starch damage probably improve gelatinization of starch resulting in superior dough quality. Desikachar and Chandrasekhar (1982) suggested the addition of pregelatinized starch or puffed cereal flours to sorghum flour for increased water absorption and improved dough quality. They also started that sorghum varieties with a low gelatinisation temperature (GT), high peak viscosity (PV) and setback and high water uptake give dough with better rolling quality. Sorghum varieties with high GT and low PV and setback can show good *mudde (Sankati)* quality. The results obtained suggested that it is worthwhile to study percent starch damage, water retention capacity and rolling quality of a large number of genotypes and explore

Table 4: Correlation coefficients (r) between flour quality components*

Percent starch damage vs water retention capacity	0.89
Percent starch damage vs rolling quality of dough	0.82
Percent starch damage vs volume of water required for dough	0.65
Water retention capacity vs rolling quality	0.80
Water retention capacity vs volume of water	0.83
Rolling quality vs volume of water required for dough	0.69
% Flour through 75 mu vs gel spread	0.75
% Flour through 75 mu vs rolling quality	−0.42
Rolling quality vs extrusion force	−0.63

* Based on 36 flour samples; r values significant at 1 % probability Level = 0.42.

their value in devising rapid tests to predict dough quality.

Correlations between the grain hardness measurements (% floaters and pearling index) and percent starch damge and water retention capacity were high (> 0.6) and showed that hard grains may tend to get more starch damaged in the *chakki* and Udy mills. Flour from the laboratory mill did not exhibit such a trend. The range ,of quality parameters of laboratory milled flour was narrow compared to that of other mills. These results point out the possible interaction between grain hardness and milling system and their effect on product quality.

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LITERATURE CITED

American Association of Cereal Chemists Approved Methods, Vol II, AACC 1969.

AOAC. 1975. Association of Official Analytical Chemists, 1975, Official Methods of Analysis. 12th ed. The Association, Washington D.C.

Desikachar, H.S.R. and Chandrasekhar, A. 1982. Quality of sorghum for use in Indian Foods. p. 262-268 In Proceedings of International Symposium on Sorghum Grain Quality, 28-31 October 1981, ICRISAT, Patancheru, (AP), India.

Hallgren, L. and Murty, D.S. 1983. A screning test for grain hardness in sorghum employing density grading in sodium nitrate solution. Journal of Cereal Science 1:265-274.

Kirlies, A.W. and Crosby, K.D. 1982. Sorghum hardness: Comparsion of methods for its evaluation. In Proceedings of International Symposium on Sorghum Grain Quality, p 231-241, 28-31 October 1981, ICRISAT-Patancheru, A.P., India.

Murty, D.S. and Subramanian V. 1982. Sorghum Roti: I. Traditional methods of consumption and standard procedures for evaluation. In Proceedings of International Symposium on Sorghum Grain Quality, p. 73-78, 28-31 October 1981, ICRISAT-Patancheru, A.P., India.

Murty, D.S., H.D. Patil and House, L.R. 1982a. Sankati quality evaluation of sorghum cultivars, p. 36-38 In Proceedings of International Symposium on Sorghum Grain Quality, 28-31 October 1981, ICRISAT-Patancheru, A.P., India.

Murty, D.S., H.D. Patil and House, L.R. 1982b. Sorghum *roti:* II. Genotypic and environmental variation for roti quality parameters. p. 79-91 In Proceedings of International Symposium on Sorghum Grain Quality, 28-31 October 1981, ICRISAT-Patancheru, A.P., India.

Murty, D.S., H.D. Patil and House, L.R. 1982c. Cultivar differences for gel consistency in sorghum. p. 289-293 In Proceedings of International Symposium on Sorghum Grain Quality, 28-31 October 1981, ICRISAT-Patancheru, A.P., India.

Singh, U. and Jambunathan, R. 1980. Evaluation of rapid methods for the estimation of protein in chickpea (Cicer arietinum L.). J. Sci. Food Agric. 31:247-254.

Singh, U., Jambunathan, R. and Narayanan, A. 1980. Biochemical changes in developing seeds of pigeonpea (Cajanus cajan L.). Phytochemistry 19:1291-1295.

Sollars, W.F. 1972. Relation of distilled water retention to alkaline water retention, water absorption and baking properties of wheat flour. Cereal Chem. 49:168-172.

Subramanian, V., Jambunathan, R. and Sambasiva Rao, N. 1984. Textural properties of sorghum dough. Journal of Food Science (In Press).

Vogel, S. and Graham, M. 1979. Sorghum and millet: food production and use: Report of a workshop held in Nairobi, Kenya. 4-7 July 1978. IDRC-123, Ottawa, Ontario, Canada, IDRC. 64 pp.