Studies on Flour Particle Size and Endosperm Texture in Sorghum

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Flour particle size distribution of two sorghum cultivars was studied using three grinding and sieving methods. Sieve shaking machines provided a spurious picture of flour particle size distribution, due to agglomeration of fine particles on the sieves. Significant differences in flour particle size were observed between 15 cultivars, using hand sifting procedures. Endosperm texture was evaluated by three methods: estimation of breaking strength, microscopic observation of vitreousness and pearling grains with a seed scarifier. The parameters, % corneous endosperm, % pearling loss and % brokens were higly correlated between themselves and with % flour $<75\,\mu$m. The coefficient of variation was the lowest for the parameter % flour $<75\,\mu$m, which gave a reliable indication of grain hardness.

Sorghum (*Sorghum bicolor* (L.) Moench) is the staple food of millions of people in India and Africa. The ease of preparation and acceptance of sorghum food products is dependent on the texture of the grain[1]. Studies made on the milling quality of sorghum using a Strong Scott barley pearler showed that endosperm texture was related to milling quality and grain hardness[2]. Kirleis and Crosby[3] found that pearling and particle size indices offer sensitive and rapid measures of sorghum grain hardness. However, information on flour particle size in sorghum is limited and contradictory. Waniska[4] found significant differences in flour particle size between cultivars and noted that hard grains yielded flour with a fine particle size. Similar results were obtained by Murty *et al.*[5] using Waniska's methods of particle size analysis. However, Kirleis and Crosby[3] observed that hard grains produced a coarser flour than soft grains. Alicia de Francisco *et al.*[6] evaluated three sorghum cultivars and found that the flour particle size of Dwarf White was small, although it had a relatively hard endosperm. A critical study of the methods followed by these workers showed that the grinding and sieving techniques used were different. Therefore, a comparative study of flour particle size distribution in sorghum cultivars was undertaken by using three grinding and seiving methods. Attempts were also made to evaluate endosperm texture with a seed scarifier and to relate the texture to flour particle size.

Materials and Methods

Bulk samples of grain harvested during March 1982 from white pericarp sorghum cultivars, grown at the ICRISAT Center (Patancheru) in comparable field plots, were chosen for the present studies. All the samples were dried to a uniform moisture level (10 ± 1 per cent) and stored at ambient temperature for further analyses. In one experiment, bulk samples of two cultivars, 'M 35-1' and 'SPV 386' were ground in three different mills: (*a*) a domestic carborundum grinder (Milcent D-2) with vertically placed stones; (*b*) a village flour mill or *chakki* equipped with horizontally placed stones; and (*c*) a Udy Cyclone mill with a 0.4 mm screen. The stone grinders were operated at a constant speed and setting. During each run the middle portion of the flour output was collected. The flour samples were stored at 8°C until the sieve analyses were carried out.

Five lots of flour were taken from each treatment and were sifted by five sieving methods: (*i*) by hand until no more flour passed through, (*ii*) sieving with a RoTap Sieve Shaker (Tyler) for 30 min. (*iii*) sieving with RoTap Sieve Shaker for 60 min, (*iv*) sieving with Portable Sieve Shaker (Tyler Rx-24) for 30 min, and (*v*) sieving with Portable Sieve Shaker for 60 min. Flour samples (25 g) taken for sieve analyses were kept in an oven at 70°C for two hours and then cooled in a desiccator. The samples were sieved using a series of US standard sieves. The sieve shakers were loaded with sieves of pore sizes

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250, 180, 150, 125, 106 and 75 μm in that order from top to bottom and the throughs of 75 μm were collected in a pan. Hand sifting was done using the same set of sieves. Flour was shaken and carefully rubbed with a fine hair brush on the sieve mesh. Flour samples of two cultivars, 'E 35-1' and '296B' were ground in the domestic grinder and were observed for their particle size distribution both by hand sifting and by using an Alpine Air-jet Sifter (Augsberg).

In another experiment, grain samples from 15 cultivars (Table 3) were ground in the domestic carborundum grinder, and particle size analysis of the resulting flour was carried out only by the hand sieving method. The experiment was repeated over three consecutive weeks and during each week three independent observations on particle size were made for each cultivar. Grain samples were evaluated for texture by using there parameters: breaking strength, per cent corneous endosperm and pearling losses. Breaking strength (kg) of the grain was observed for three individual grains in each week by using a Kiya rice hardness tester[5]. During each week longitudinal sections of three randomly chosen grains from each cultivar were observed under a light microscope. The vitreous and floury portions of the endosperm were traced on to graph paper using a Camera lucida and the proportion of vitreous area was expressed as per cent corneous endosperm.

Pearling quality of one sample from 13 cultivars was evaluated each week by using a Forsberg seed scarifier (Forsberg's Inc; Minnesota, USA) generally used to scarify legume seeds to hasten their germination. The scarifier consists of a drum (13×15 cm) in which four rotating blades (2.5×11.5 cm) are fixed at the bottom and are connected to a shaft powered by an electric motor (HP 1/3, RPM 1725). A cylindrical lid (12.5×15.4 cm) fits into the drum and is provided with a special sand paper on the walls. A 20 g sample was placed in the lid and scarification was carried out for 45 sec. The resulting sample was carefully recovered and sifted through an 850 μm screen to remove the bran. The throughs were expressed as pearling loss on per cent basis. The pearled product or overs were sifted on a 1700 μm screen and the throughs were expressed as brokens on per cent basis.

Results and Discussion

Flour particle size distribution data obtained using the five sieving procedures are presented in Table 1. When the shaking machines were used, the percentage of flour that passed through the 75 μm sieve was negligible while the corresponding amount for hand sieving was several times higher. For the convenience of tabular presentation, percentage of flour of <125 and <75 μm only are given for the sieve shakers. More than 80 per cent of the flour was held over the 180 μm screen when either of the sieve shakers were used. Agglomeration of fine particles on the sieve apparently blocked the passage of flour when the sieves were shaken. Agglomeration of flour may not pose serious problems if coarse meal or grits were to be studied by using sieve shakers. The finer the flour under study the more spurious are the values given by the shakers. When bouncers like rubber balls and plastic bangles were used on the sieves, improvement in the flour passage was small or negligible. Thus, flour particle size distribution

TABLE 1. FLOUR PARTICLE SIZE (μM) DISTRIBUTION (PER CENT) OF TWO SORGHUM CULTIVARS OBTAINED BY USING DIFFERENT GRINDING AND SIEVING METHODS*

	Hand sifting							RoTap sieve shaker				Portable sieve shaker	
	>250	>180	>150	>125	>106	>75	<75	30 min		60 min		30 min	60 min
								<125	<75	<125	<75	<125	<125
M_1C_1	0.5	2.4	1.8	4.2	5.7	12.5	73.5	2.0	0.1	4.5	0.4	0.0	0.0
M_1C_2	1.9	4.2	4.5	6.6	8.7	15.2	59.2	0.8	0.0	2.4	0.1	0.0	0.0
M_2C_1	2.9	5.9	5.7	8.9	8.8	15.7	52.2	1.7	0.1	1.8	0.1	0.0	0.0
M_2C_2	6.3	8.7	6.1	10.4	8.3	13.6	46.6	1.6	0.1	2.9	0.3	0.0	0.0
M_3C_1	9.6	9.1	5.1	5.9	6.1	11.9	52.2	0.9	0.0	5.1	0.1	0.0	0.0
M_3C_2	9.8	9.4	5.5	7.3	5.2	13.2	49.8	7.9	1.4	6.0	1.4	0.0	0.1
CD 5%	1.0	1.0	2.8	1.1	1.0	0.9	3.4	1.6	1.8	2.4	0.5	0.1	0.1
CV%	8.0	6.1	23.0	6.1	5.8	2.8	2.3	47.0	2.8	68.0	5.5	0.0	0.0

*Average of two observations.

M_1 = Domestic grinder, M_2 = Village flour mill, M_3 = Udy-Cyclotec Mill.

C_1 = Cultivar 'M 35-1', C_2 = Cultivar 'SPV 386'.

TABLE 2. FLOUR PARTICLE SIZE DISTRIBUTION OF TWO SORGHUM CULTIVARS ANALYSED BY TWO SIEVING METHODS

Cultivars	Sieving method	% flour accumulated through sieve of indicated size (μm)								
		250	180	150	125	106	100	75	71	63
E 35-1	Hand sieving	95.6	86.8	78.1	65.7	55.6	—	40.5	—	—
	Alpine air-jet sifter	97.0	84.5	75.0	62.0	—	49.5	—	33.5	26.0
296B	Hand sieving	98.0	93.9	90.1	83.0	75.8	—	61.0	—	—
%CV	Alpine air-jet sifter	98.0	94.5	90.5	81.0	—	71.0	—	54.0	41.0

obtained on sieve shakers needs to be cautiously interpreted particularly when the flour contains intermediate or fine particles. Data obtained by hand sieving showed that per cent flour of <75 μm produced in the domestic grinder was higher compared to that obtained in the village flour mill and Udy mill (Table 1). Both hand sieving and the Alpine Laboratory Air-jet Sifter yielded comparable particle size values indicating that hand sifting with the help of a standard sieve and a fine hair brush could be used reliably in the absence of sophisticated sieving devices (Table 2).

Observations made in the second experiment on flour particle size, endosperm texture and pearling behaviour of the 15 cultivars are presented in Table 3. The flour particle size distribution curves are shown in Fig 1. On an average, 63 per cent of the flour produced in the domestic mill was composed of particles <75 μm and 15 per cent of particles larger than 125 μm. The coefficient of variation for per cent flour <75 μm was only 2.8 per cent and was the most reliable parameter studied. The percentage of flour that passed through the 75 μm screen ranged from 46 to 82 and was highly correlated with percentage of flour >125 μm (r=0.96). Flour from the floury endosperm types such as 'IS 1401' and 'P-721' had the greatest proportion of particles <75 μm. The vitreous grain types such as '2219B' and 'E 35-1' produced flour with the lowest proportion of particles <75 μm size. The proportion of corneous endosperm

TABLE 3. ENDOSPERM TEXTURE AND MILLING PROPERTIES OF 15 SORGHUM CULTIVARS*

Cultivar	100 grain wt. (g)	% corneous endosperm	Breaking strength (kg)	% pearling loss	% brokens	% flour >125 μm	% flour <75 μm
M 35-1	3.92	32.5	5.7	28.0	9.8	9.13	74.4
2077B	2.30	49.2	4.1	28.1	21.6	8.87	72.4
IS 1401	3.00	4.0	4.3	36.0	37.8	7.48	80.9
IS 5604	2.31	48.1	5.0	17.4	3.5	24.75	49.2
CSH 6	2.82	50.1	6.1	13.9	2.0	20.64	48.0
E 35-1	3.50	68.4	11.0	15.6	0.9	19.50	48.8
SPV 351	2.50	61.6	8.1	12.9	0.8	22.17	46.2
SPV 422	3.27	57.8	7.9	27.3	3.3	11.04	67.2
CSH 8	4.10	49.3	5.8	25.3	25.4	11.47	65.0
296B	3.07	48.1	6.3	22.2	16.0	12.86	65.9
2219B	2.29	80.2	6.5	14.7	2.1	23.17	45.6
P721	2.15	5.8	5.2	—	—	10.43	78.4
S 29	2.43	75.1	7.2	19.6	4.4	17.47	55.8
IS 9985	5.46	45.1	6.1	—	—	6.26	81.5
SPV 393	2.72	57.2	6.8	15.5	6.3	14.47	61.7
Mean	3.05	48.8	6.4	21.4	10.8	14.62	62.7
SE	0.02	1.17	0.13	0.76	0.8	0.32	0.47
%CV	2.1	27.8	7.9	6.1	12.5	8.6	2.8

*Hundred grain weight, breaking strength, % corneous endosperm, % flour >125 μm and % flour <75 μm were averaged over 9 observations. Per cent pearling loss and % brokens were averaged over 3 observations.

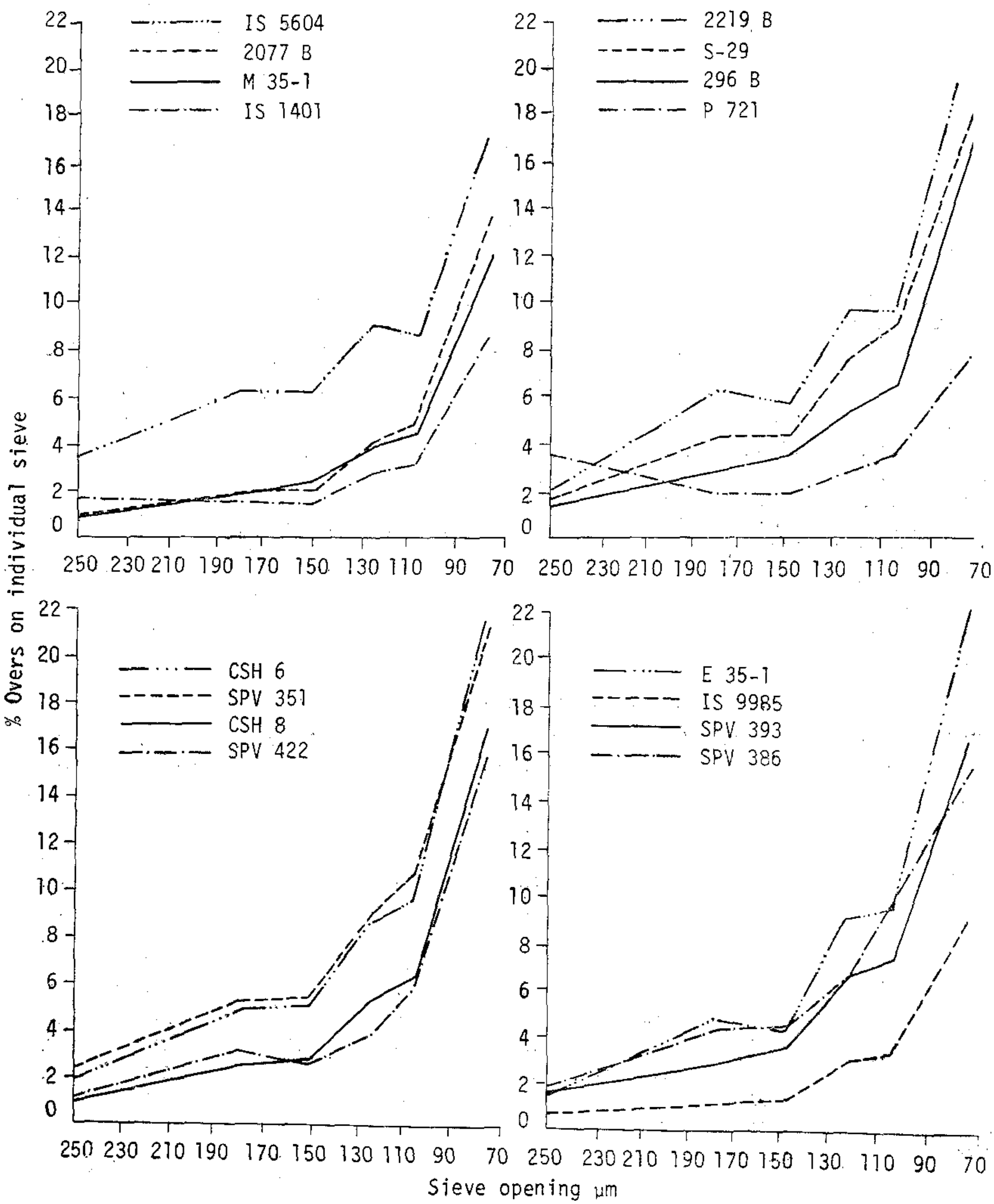

Fig. 1. Flour particle size distribution in sorghum.

varied from 49 to 80 per cent and was highly corrleated with percentage of flour $<75\mu m$ ($r = -0.73$, significant at 1 per cent probability). Kirleis and Crosby[3] also observed a strong correlation between endosperm vitreousness and particle size.

Breaking strength of the grains as determined by the

Kiya rice hardness tester varied from 4.1 to 8.1 kg with the exception of the cultivar, 'E 35-1' which has turtle shaped grains with a flat surface on one side. Kiya rice hardness tester observations on sorghum are affected by grain shape and could be misleading[1]. The correlation coefficients between breaking strength and corneousness, pearling losses and flour particle size were relatively low and statistically insignificant.

The amount of bran lost during scarification or per cent pearling loss for the 13 cultivars ranged from 13 to 36 and was positively correlated with per cent brokens ($r=0.82$) and per cent flour $<75\mu m$ ($r=0.94$). Per cent pearling loss was also negatively correlated with per cent corneous endosperm ($r=0.74$) showing that estimates of pearling losses could be used to evaluate the hardness of the grain. Shepherd[7] and Oomah *et al.*[8] described novel laboratory pearling devices that could be used to evaluate dehulling quality and hardness of sorghum grains. The scarification equipment used here provided adequate information on the hardness of the sorghum samples studied and the coefficient of variation (6 per cent) was much lower than that for the microscopic evaluation of corneousness. However, pearling behaviour is also affected by grain size and shape[3]. The mechanism of scarification involves whirling and abrasion of the grain against a sand-paper present on the inner surface of the scarifying drum. Further investigations are necessary to determine how accurately the pearling quality results obtained with the scarifier could predict the behaviour of sorghum samples in commercial pearlers where different techniques may be used[9,10].

These studies demonstrate that because of the agglomeration problems posed by fine flour particles, appropriate sifting techniques should be used to evaluate particle size. Endosperm texture, pearling quality and flour particle size measurements are highly associated and could be used to evaluate grain hardness in sorghum. Flour particle size analysis was the most reliable parameter to distinguish sorghum samples. The relative merit of the three different mills in the evaluation of grain texture and flour particle size could not be judged from the present data, as only two cultivars were compared. Apparently, the Udy mill is convenient because only small grain samples are required.

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References

1. Rooney, L. W. and Murty, D. S., Evaluation of sorghum food quality. *Sorghum in the Eighties: Proceedings of the International Symposium on Sorghum*, 2–7, Nov, 1981, International Crops Research Institute for the Semi-Arid Tropics, Patancheru, A. P., India, 1982, 571.
2. Maxson, E. D., Fryar, W. D., Rooney, L. W. and Krishna Prasad, M. N., Milling properties of sorghum grain with different proportions of corneous to floury enodsperm. *Cereal Chem.*, 1971, **48**, 478.
3. Kirleis, A.W. and Crosby, K.D., Sorghum hardness: comparison of methods for its evaluation. *Proceedings of International Symposium on Sorghum Grain Quality*, 28-31 Oct., 1981, International Crops Research Institute for the Semi-Arid Tropics, Patancheru, A. P., India, 1982, 231.
4. Waniska, R.D., *Methods to Assess Quality of Boiled Sorghum, Gruel and Chapaties from Sorghum with different kernel Characters.* 1976, M. S. Thesis, Texas A & M University, College Station, Texas, USA.
5. Murty, D. S., Patil, H. D. and House, L. R., Sorghum roti. II. Genotypic and environmental variation for roti quality parameters. *Proceedings of the International Symposium on Sorghum Grain Quality*, 28-31, Oct. 1981, International Crops Research Institute for the Semi-Arid Tropics, Patancheru, A. P., India, 1982, 79.
6. De Franscisco, Alicia, Varriano-Marston, E. and Hoseney, R.C., Hardness of pearl millet and sorghum. *Cereal Chem.*, 1982, **59**, 2.
7. Shepherd, A. D., Laboratory abrasive decorating mill for small grains. *Cereal Chem.*, 1979, **56**, 517.
8. Oomah, B. D., Reichert, R. D. and Youngs, C. G., A novel multi-sample tangential abrasive dehulling device (TADD). *Cereal Chem.*, 1981, **58**, 392.
9. Desikachar, H.S.R., Pearling and milling studies on sorghum. *Proceedings of the International Symposium on Sorghum Grain Quality*, 28-31 Oct., 1981, International Crops Research Institute for the Semi-Arid Tropics, Patancheru, A.P., India, 1982, 194.
10. Munck, L., Bach Knudsen, K. E. and Axtell, J. D., Industrial milling of sorghum for the 1980s. *Sorgum in the Eighties: Proceedings of the International Symposium on Sorghum* 2–7 Nov., 1981. International Crops Research Institute for the Semi-Arid Tropics, Patancheru, A.P., India, 1982.