Physical and Chemical Characteristics of Pearl Millet Grains and Their Relationship to *Roti* Quality

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ABSTRACT

Physical characteristics such as swelling capacity of grain and flour and water-soluble flour fraction, and chemical characteristics such as protein, starch, amylose, soluble sugars and fat content in pearl millet (*Pennisetum americanum* (L.) *Leeke*) grains from 20 cultivars comprising local types, popular hybrids and prerelease lines were determined. *Rotis* were made from the grains of the 20 cultivars and evaluated for color, texture, odor, taste, and acceptability by a trained taste panel. The correlations between physicochemical characters and *roti* quality of 20 cultivars were worked out. The swelling capacity, water-soluble flour fraction, water-soluble protein, and amylose content of flour influenced the *roti* quality.

INTRODUCTION

PEARL MILLET [*Pennisetum americanum* (L.) *Leeke*] is an important cereal, contributing to the calorie and protein requirements of people in the semi-arid tropics (SAT). It is grown mostly in regions of low rainfall and is capable of withstanding adverse agroclimatic conditions. About 85% of the production is used for human consumption, particularly in the SAT regions of Africa and Asia. Several food preparations are made from pearl millet, in Africa and India (Vogel and Graham, 1979; Subramanian and Jambunathan, 1980a). *Roti* or *chapati* an unleavened flat bread, is the most common product made from pearl millet in India. Information on the food quality attributes of this product and on the physical and chemical characteristics of pearl millet is rather limited. Studies on wheat and rice have led to the identification of grain components such as proteins, pentosans, amylose, lipids, and ash, as important characteristics that influence the quality of food products (Kent, 1975; Juliano, 1979). This information has helped in breeding better varieties well suited to the preparation of various food products. A knowledge of the relationship between the physical and chemical characteristics and the overall quality of the food products made from pearl millet would therefore be useful. The purpose of this paper is to report the relationships between certain physical and chemical characteristics and sensory quality of *roti* of 20 diverse pearl millet cultivars.

MATERIALS & METHODS

Grain samples

Grain samples of 20 pearl millet cultivars consisting of local types, popular hybrids, and prerelease lines in India were obtained from different sources (Table 1). The whole grain was ground in a Udy cyclone mill (UD mill, Tecator Udy Co., Boulder, Co, USA) fitted with a screen having 0.4 mm holes and hereafter referred to as flour. The average moisture content of flours was 7.4%. The fat content was estimated by extracting the flour with n-hexane for 5 hr using a Soxhlet apparatus (AOAC, 1975). Defatted flour was used for all further analyses. All the analyses were done in duplicate and average values are reported.

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Physical characteristics

Swelling capacity. The swelling capacity of grain was measured as follows: Ten grains were weighed and transferred to a tube containing 15 mL distilled water. The tube was placed in a heating block at 90°C for 1 hr, and shaken periodically. After cooling, the excess water was decanted; the weight of the grains determined after absorbing excess water on a blotting paper. The results were expressed as a ratio of the final weight (w_f) to the initial weight (w_i). To determine the swelling capacity of flour, 0.5g flour was weighed into a 15 mL graduated centrifuge tube. Distilled water was added from a burette to the 5 mL mark and the volume of water noted (v_i). The flour and water were quantitatively transferred into a 50 mL tube, using an additional 10 mL distilled water, and then placed in a heating block at 90°C for 1 hr, with periodic shaking. After cooling, the suspension was transferred to a graduated centrifuge tube and centrifuged at 5000 rpm (3015 × *g*) for 10 min. The supernatant was discarded. The excess water adhering on the sediment was removed using a tissue paper. The volume of the wet sediment was measured as described above (v_f). The weight of the wet sediment was also determined (w_f). Results were expressed as a ratio of the final volume (v_f) or weight (w_f) to the initial volume (v_i) or weight (w_i) and reported as swelling capacity of flour on volume as well as weight basis.

Water soluble flour fraction (WSFF). Fifteen mL water were added to 0.5g flour in a tube and heated in a heating block for 1 hr at 90°C with periodic shaking. The suspension was cooled, centrifuged at 7000 rpm (5910 × *g*) for 15 min, and the supernatant saved. The residue was washed twice with a small quantity of water, and recentrifuged. The supernatants were pooled and made up to 50 mL. A 10 mL aliquot was evaporated to dryness at 110°C and the weight of the material determined. The results were expressed as mg WSFF per 100g flour.

Chemical constituents

Protein. Total nitrogen was determined using the micro-Kjeldahl procedure (AOAC, 1975); the values were multiplied by 6.25 and expressed as per cent crude protein. The water-soluble protein of flour was extracted by shaking 1g flour with 15 mL water in an Erlenmeyer flask for 2 hr, using a reciprocating shaker at room temperature (28°C). The extraction was repeated twice for 1 hr, using 10 mL water each time. The contents were centrifuged after each extraction at 7500 rpm (6785 × *g*) for 15 min. The combined extracts were made up to 50 mL; a 10 mL aliquot was treated with trichloroacetic acid (TCA) (50%, w/v) to yield a final concentration of 10% TCA, and kept at 4°C overnight. The suspension was centrifuged at 7500 rpm (6785 × *g*) for 15 min, the sediment dissolved in 1 mL 0.1 NaOH, and the protein content in the solution was determined by the method of Lowry et al. (1951).

Carbohydrates. Starch content was determined using glucoamylase enzyme according to Singh et al., (1980). Total amylose was determined using the method of Williams et al., (1958). Water-soluble amylose was determined colorimetrically (Juliano et al., 1968).

Soluble sugars were extracted from the flour using 80% ethanol (v/v) for 6 hr in a Soxhlet apparatus. After evaporating the ethanolic extract *in vacuo*,the contents were dissolved and made up to 100 mL with distilled water. Total soluble sugars were estimated using a 1 mL aliquot by the phenol-sulphuric acid method (Dubois et al., 1956).

Dough and *roti* preparation

Rotis were prepared from the whole flour of pearl millet as described by Murty and Subramanian (1982). The grains were ground using a Udy (UD) cyclone mill. The mill was fitted with a screen having 0.5 mm holes to obtain a medium fine flour. To 50g flour, hot water (about 90°C) was added in small increments, mixed well

Table 1—Pearl millet cultivars used in the study[a]

Cultivars	Type	Origin	Growing season/Location
WC-C 75	Variety	ICRISAT	Kharif, 1979 ICRISAT
MC-K 77	Experimental Variety	ICRISAT	Kharif, 1979 ICRISAT
SSC-H 76	Experimental Variety	ICRISAT	Kharif, 1979 ICRISAT
ICH 241	Hybrid	ICRISAT	Kharif, 1979 ICRISAT
ICH 226	Hybrid	ICRISAT	Kharif, 1979 ICRISAT
ICMS 7703	Synthetic	ICRISAT	Kharif, 1979 ICRISAT
PSB 8	Synthetic	PAU	Kharif, 1979 ICRISAT
BK 560	Hybrid	Commercial	Kharif, 1979 ICRISAT
UCH 4	Hybrid	TNAU	Kharif, 1979 ICRISAT
HS 1	Variety	HAU	Rabi, 1979 ICRISAT
DC 3	Composite progeny	IARI	Rabi, 1979 ICRISAT
BJ 104	Hybrid	MAHYCO	---
MBH 110	Hybrid	MAHYCO	---
15 P Synthetic	Synthetic	Agrl. College, Jobner (Rajasthan)	- Jobner
Joli	Local	Jobner (Rajasthan)	- Jobner
Uujivm	Local	Jobner (Rajasthan)	- Jobner
Ardibi	Local	Jobner (Rajasthan)	- Jobner
LCE 1	Local	Jobner (Rajasthan)	- Jobner
LCB 10	Local	Jobner (Rajasthan)	- Jobner
Local (Gujarat)	Local	Anand (Gujarat)	- -

[a] ICRISAT — International Crops Research Institute for the Semi-Arid Tropics;
PAU — Punjab Agricultural University;
TNAU — Tamil Nadu Agricultural University;
HAU — Haryana Agricultural Univeristy;
IARI — Indian Agricultural Research Institute
MAHYCO — Maharashtra Hybrid Seed Company
Kharif — rainy season;
Rabi — post-rainy season.

Table 2—Physical characteristics of pearl millet grain and flour

	Swelling capacity[a]			
	of grain	of flour		WSFF[b]
Cultivar	w_f/w_i	v_f/v_i	w_f/w_i	(mg/100g)
WC-C 75	2.9	2.1	3.8	47.7
MC-K 77	2.6	3.1	4.3	47.7
SSC-H 76	2.9	3.1	5.7	44.6
ICH 241	3.1	1.5	2.6	58.3
ICH 226	2.2	1.6	2.7	63.6
ICMS 7703	2.6	2.8	5.1	54.5
PSB 8	2.9	2.1	3.6	53.5
BK 560	2.7	1.7	3.1	57.8
UCH 4	2.7	3.4	6.2	50.8
HS 1	2.8	5.5	9.3	25.9
DC 3	2.8	5.5	9.0	28.4
BJ 104	2.7	5.1	8.6	31.6
MBH 110	3.0	6.1	10.1	29.8
15 P Synth	2.3	5.4	9.8	28.8
Joli	3.0	5.2	10.0	30.1
Uujivm	2.5	5.2	8.3	28.1
Ardibi	2.8	5.3	9.0	26.9
LCB 1	2.5	5.7	9.7	28.2
LCB 10	2.6	5.3	9.8	23.7
Local (Gujarat)	2.7	5.7	9.7	26.3
Mean	2.7	4.1	7.0	39.5
S.E.[c]	0.05	0.37	0.64	3.03

[a] V_i — initial volume before swelling; v_f — final volume after swelling; w_i — initial weight before swelling; w_f — final weight after swelling.
[b] Water-soluble flour fraction.
[c] S.E. — Standard error for comparing cultivar means.

and kneaded by hand until appropriate consistency was obtained. The volume of water required to achieve the desired dough consistency was noted and calculated as mL required for 100g flour. After kneading well, the cohesiveness of dough was subjectively evaluated using a score of 1 to 3, where 3 is good and 1 is poor, and expressed as kneading quality.

For evaluating rolling ability, the dough was prepared as described above using another 50-g sample of flour. The dough was pressed into a small disc by hand and rolled into a round shape to a uniform thickness of 2.5 mm on a smooth laminated board with raised edges, using a wooden rolling pin. Four to five grams dry flour were sprinkled on the surface to prevent the dough from sticking to the board or the pin. The maximum diameter, in mm, to which the dough could be rolled until it broke was measured, and expressed as rolling quality. The rolled dough was cut into disc, 20 cm diameter, and baked on a flat baking pan, at 260–270°C. Baking was considered complete when uniform puffing with intermittant brown spots appeared on the surfaces. The *roti* was removed from the baking pan. The time taken for baking and the moisture loss in *roti* during baking were recorded.

Rotis were evaluated for sensory qualities using a 10 member trained panel. The panelists were trained extensively using a standard check (BJ-104) sample. Two *rotis* were prepared from each pearl millet cultivar. Each *roti* was cut into five uniform pieces and one piece was supplied to each panelist. The samples were coded with three digit random numbers. Five test samples were supplied at a time including the standard check. Testing of the samples was done in partioned booths, under incandescent lights. The temperature of the booths was between 28° and 30°C.

The panelists scored the *roti* for color and appearance, texture, odor, taste and acceptability and they rinsed their mouths with water after testing each sample. The following scores were used for the various sensory parameters: color and appearance: 4-very desirable, 1-undesirable; texture: 4-very soft, 1-very hard; odor: 4-excellent, 1-poor; taste: 4-excellent, 1-poor; acceptability: 4-excellent, 1-poor.

Statistical analysis

The mean values from duplicate analyses of 20 cultivars for physical characteristics, chemical factors, and dough and *roti* quality were used for calculating Standard Error (SE) for comparing cultivars. The correlation coefficients among the various physicochemical characters were determined by comparing individual mean values of all the 20 cultivars using the simple correlation method (Snedecor and Cochran, 1967). Similarly, the correlations between *roti* sensory quality and physicochemical characters were determined.

RESULTS & DISCUSSION

Physical and chemical characteristics

The *roti* quality of sorghum was influenced by the physicochemical characteristics of grain (Subramanian and Jambunathan, 1982). The physical characteristics of grain and flour from 20 pearl millet cultivars were given in Table 2. The swelling capacity of grains did not show wide variation. However, swelling capacity of flour showed appreciable variation. There was also considerable variation in the WSFF among the cultivars (Table 2).

The chemical composition of the pearl millet flours used in the study are given in Table 3. Crude protein content showed wide variation. Water-soluble protein content was low and the variation among the cultivars was low. Cagampang and Kirleis (1984) reported that soluble protein, total amylose, and soluble

Table 3—Chemical composition of pearl millet flour

Cultivar	Crude protein (%)	Water-soluble protein (%)	Starch (%)	Amylose (%)	Water-soluble amylose (%)	Soluble sugars (%)	Fat (%)
WC-C 75	11.1	0.78	66.3	26.9	2.1	2.0	4.9
MC-K 77	11.3	0.85	69.5	27.8	3.2	2.2	4.7
SSC-H 76	10.7	0.81	68.1	27.5	3.4	2.0	4.6
ICH 241	12.7	0.91	66.1	28.8	1.7	1.9	4.2
ICH 226	11.3	0.65	67.5	26.9	2.7	2.2	3.9
ICMS 7703	11.4	0.85	66.6	26.7	3.2	2.0	4.6
PSB 8	12.0	0.76	66.9	26.3	1.7	1.9	4.4
BK 560	12.2	0.65	64.2	27.3	2.0	2.1	4.2
UCH 4	10.9	0.82	70.2	28.5	3.5	2.0	4.5
HS 1	12.8	1.26	66.4	25.7	3.1	2.1	4.6
DC 3	13.5	1.04	64.5	25.4	2.8	2.1	5.1
BJ 104	12.4	1.11	67.9	25.7	3.6	1.8	4.7
MBH 110	11.6	1.32	67.9	25.7	3.4	1.7	4.5
15 P Synth	13.7	1.12	63.6	24.9	2.7	2.1	4.4
Joli	12.1	1.03	66.9	25.8	3.8	3.8	5.0
Uujivm	15.6	1.18	62.8	23.6	2.8	2.2	5.5
Ardibi	13.3	1.06	65.8	25.1	2.8	2.0	4.4
LCB 1	11.9	0.98	66.3	25.3	2.4	2.0	4.5
LCB 10	13.8	1.06	66.1	24.9	2.4	2.0	4.6
Local (Gujarat)	8.6	0.88	68.5	28.5	3.2	2.0	5.1
Mean	12.2	0.96	66.6	26.4	2.8	2.0	4.6
S.E.[a]	0.33	0.04	0.42	0.31	0.14	0.09	0.08

[a] S.E. — Standard error for comparing cultivar means.

Table 4—Correlation (r) among physicochemical characteristics of pearl millet grain (n=20)

Characteristics	Protein	Water-soluble protein	Amylose	Water-soluble amylose
Swelling capacity of flour				
(v_f/v_i)[a]	0.26	0.83**	−0.61**	0.50*
(w_f/w_i)	0.26	0.81**	−0.60**	0.50*
WSFF[b]	−0.36	−0.83**	0.66**	−0.35
Protein	1.00	0.51*	−0.77**	−0.22
Water-soluble protein	0.51*	1.00	−0.65**	0.37
Starch	−0.76**	−0.25	0.64**	0.45*
Amylose	−0.77**	−0.65**	1.00	0.06
Water-soluble amylose	−0.22	0.37	0.06	1.00
Soluble sugars	0.23	−0.25	−0.08	−0.08
Fat	0.18	0.36	−0.31	0.30

[a] v_f/v_i = final/initial volume; w_f/w_i = final/initial weight.
[b] Water-soluble flour fraction.
* Significant at 5% level; ** Significant at 1% level.

amylose contents in sorghum were associated with the quality of the cooked sorghum.

Starch is the major component of pearl millet grain. Total amylose content of the pearl millet cultivars showed only minor variation (Table 3). The swelling and solubility properties of sorghum starches are correlated with the amylose content of the starch (Akingbala et al., 1982). Sugars impart a characteristic taste for foods; however, the range of sugar values for the pearl millet cultivars is low. The fat content of millet was comparatively higher than that of sorghum or wheat (Perten, 1977) and variation existed among the pearl millet cultivars.

Relationship between physical/chemical characteristics

Individual values of the various physical and chemical characteristics of the 20 cultivars were compared using the coefficient of linear correlation method. The values for a few of the factors are given in Table 4. The swelling capacity of flour (v_f/v_i) had significant positive relationships with water-soluble protein and water-soluble amylose and negative relationship with total amylose. Waniska (1976) observed a negative relationship between swelling power and amylose. There was a significant negative correlation between the amylose contents of flour and total protein and water-soluble protein, but a positive correlation with WSFF. Starch showed a negative relationship with protein and a positive relationship with amylose. Sugars and fat did not have a significant relationship with several of the characteristics studied.

Dough and *roti* evaluation

The quantity of water required to make dough from 100g flour ranged from 67–79 mL (Table 5), indicating the difference in water absorption rates for the flours. Variation in cohesiveness of sorghum doughs has been reported (Subramanian et al., 1983). Dough made from pearl millet flours showed good cohesiveness as the kneading quality score was between 2 and 3. The rolling quality of dough did not show wide variation. The time taken for baking *rotis* ranged from 3.0–4.5 min. Differences in moisture loss during baking ranged from 19.0–28.7% for the cultivars. An optimal moisture content gives *rotis* with good acceptability (Desikachar and Chandrasekar, 1982). A good pearl millet *roti* is grey to greyish-white in color, and smooth in appearance; uniformly soft over the surface; slightly sweet in taste with characteristic millet odor. Based on the taste panel evaluations (Table 5), only three cultivars, Uujivm, LCB 10, and Local (Gujarat) were rated as the best. Five cultivars HS1, 15P Synthetic, Joli, Ardibi, LCB 1, were rated as good, and the remaining ones were rated as medium.

Relationship between *roti* quality and, physical/chemical characteristics

Our earlier studies with 16 pearl millet cultivars indicated that swelling capacity of flour, amylose, sugars, fat, and ash content jointly influenced the sensory quality of pearl millet *roti* (Subramanian and Jambunathan, 1980b). The physical and

Table 5—Dough quality and sensory scores of pearl millet rotis

Cultivar	Dough			*Roti*[b]				
	Water required for dough (mL/100g flour)	Kneading quality score[a]	Rolling quality (mm)	Color	Texture	Odor	Taste	Acceptability
WC-C 75	76	3	223	1.9	3.0	2.5	2.2	2.2
MC-K 77	76	3	225	2.2	3.1	2.5	2.3	2.1
SSC-H 76	76	3	225	2.0	2.9	2.2	2.3	2.2
ICH 241	78	3	228	1.8	2.8	2.1	2.0	2.0
ICH 226	76	3	230	1.7	2.6	2.0	1.8	1.8
ICMS 7703	77	3	225	2.2	2.9	2.4	2.4	2.3
PSB 8	79	3	223	1.8	2.5	2.4	2.1	2.0
BK 560	79	3	225	1.8	2.6	2.4	2.1	2.0
UCH 4	75	2	220	2.9	2.8	2.6	2.4	2.2
HS 1	69	3	210	3.0	2.8	3.1	3.1	3.1
DC 3	69	3	220	3.3	3.0	2.6	2.5	2.2
BJ 104	73	3	223	3.7	3.0	3.0	2.8	2.9
MBH 110	78	3	228	2.9	3.2	2.8	2.5	2.5
15 P Synth	67	3	218	3.9	2.9	3.5	3.1	3.2
Joli	76	2	223	3.4	2.9	3.1	3.0	3.0
Uujivm	74	2	221	3.9	3.2	3.6	3.6	3.7
Ardibi	74	3	228	3.8	2.9	3.3	3.1	3.0
LCB 1	75	3	225	3.6	3.3	3.0	3.1	3.1
LCB 10	67	3	218	3.9	2.9	3.4	3.4	3.5
Local (Gujarat)	71	3	228	4.0	3.1	3.4	3.3	3.4
Mean	74	2.8	223	2.9	2.9	2.8	2.7	2.6
S.E.[c]	0.85	0.08	1.03	0.20	0.05	0.11	0.12	0.13

[a] Kneading quality score: 3 = good; 1 = poor.
[b] *Roti* quality score: 4 = excellent; 1 = poor; mean of evaluation by 10 panelists.
[c] S.E. — Standard error for comparing cultivar means.

Table 6—Relationship (r) between roti sensory quality and physicochemical characteristics (n=20)

Factors	*Roti* quality				
	Color	Texture	Odor	Taste	Acceptability
Swelling capacity of flour					
v_f/v_i	0.91**	0.64**	0.83**	0.84**	0.81**
w_f/w_i	0.91**	0.58**	0.84**	0.85**	0.82**
WSFF	−0.92**	−0.59**	−0.88**	−0.89**	−0.87**
Water-soluble protein	0.69*	0.54*	0.68**	0.68**	0.67**
Amylose	−0.59**	−0.30	−0.64**	−0.62**	−0.61**
Fat	0.49*	0.58*	0.51*	0.56**	0.51*

* Significant at 5% level; ** Significant at 1% level.

chemical characteristics and the taste panel scores of *roti* from each of the 20 cultivars were tested for correlation. There was significant correlation between some of the flour characteristics and the taste panel evaluations of the *roti* (Table 6). The *roti* sensory characteristics showed significant positive correlation with swelling capacity of flour and negative correlation with WSFF. Olewnik et al. (1984) indicated that water-soluble fraction in millet did not play a major role in the physical properties of *roti*. However, the water-soluble protein of pearl millet flour showed a positive association with the taste panel evaluation. Maes (1966) reported that the baking quality of wheat flours was negatively correlated with water-soluble protein. Cagampang and Kirleis (1984) found a significant relationship between cooked grain texture of sorghum, and water-soluble protein, and total amylose. Amylose showed a negative relationship with *roti* quality characteristics of pearl millet (Table 6). Several flour components may jointly influence *roti* quality.

CONCLUSION

EVALUATION of physicochemical characteristics and sensory quality of *roti* of 20 selected pearl millet cultivars revealed basic differences among the cultivars. Swelling capacity of flour and water-soluble protein showed positive correlation with sensory quality of *roti*. Water-soluble flour fraction (WSFF) and total amylose showed negative correlation with sensory quality of *roti*. WSFF and swelling capacity of flour seem to be reliable indicators for predicting the *roti* quality of pearl millet as magnitude of their correlations are very significant. The effect of genetic component variability and the environmental effect on those relationships have to be studied before the above factors could be suggested as a tool for screening early generation material in a breeding program.

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