Sorghum and Pearl Millet

REPORT OF WORK

January - December 1985

ICRISAT

International Crops Research Institute for the Semi-Arid Tropics
Patancheru, Andhra Pradesh 502 324, India

1986

GRAIN QUALITY AND BIOCHEMISTRY
Progress Report 2/86

C E R E A L S

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FOREWORD

This report describes the various research activities carried out on biochemical, processing and food quality aspects of ICRISAT Cereals during 1985. This work was carried out by the Grain Quality and Biochemistry unit in collaboration with Sorghum/Pearl Millet Breeding units.

This is not an official publication of ICRISAT and should not be cited.

June 1987

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SORGHUM

Project No.: **S-106 (85) IC**

Project title : **Evaluation of food and nutritional quality of sorghum**

Objectives

a) To assist national and regional programs in determining characteristics of sorghum grain that contribute to the quality of specific foods in SAT.

b) To relate physicochemical, structural and processing charaters of sorghum grain to product quality.

c) To establish simple, rapid and reliable physicochemical tests useful to breeders in national programs.

d) To evalute elite breeding and standard cultivars originating from ICRISAT center as well as other national programs for food and nurtitional quality.

e) Study the variability in protein and lysine content in germplasm and breeding accessions (1985-1986).

Chemical composition and dehulling quality

Grain samples of 10 cultivars representing a wide range of endosperm texture were selected to study their physicochemical characteristics, food and nutritional quality, and processing characters. The grains from the 1984 post-rainy season harvest were used in the study. The grain samples were analysed for protein, starch,soluble sugars and fat contents. Wide variation for protein, soluble sugars and fat contents was observed among the cultivars (Table 1).

The relative proportion of the corneous to floury endosperm is rated subjectively on a scale of 1 to 5, and variation in corneousness was observed among the cultivars. Hardness or breaking strength (kg/sq.cm)of the grain was observed for 20 individual grains by using KIYA hardness tester and their mean values are given. Hardness ranged from 5.4 (SAR 1) to 8.8 (CSH 8) (Table 2).

The grain samples were dehulled using a Tangential Abrasive Dehulling Device (TADD) for 4 min and the endosperm recovery (%), the broken grain (%) and loss due to dehulling (%) were determined (Table 2). The endosperm recovery ranged from 63.5% (CSH 8) to 93.0% (DKV 3) and brokens ranged from 0.5% (S 29) to 13.2% (SAR 1) and the loss due to dehulling ranged from 6.3% (DKV 3)to 34.2% (CSH 8). The grain samples were also dehulled using a barley pearler. The endosperm recovery (%) using a barley pearler ranged from 51.4 (CSH 8) to 87.6% (DKV 3), brokens (%) ranged from 0.5 to 19.9% and loss due to dehulling (%) ranged from 11.4 (S 29) to 28.8 (ET 3491) (Table 3).

Table 1 : Protein, starch, soluble sugars and fat content of sorghum grains

Cultivar	(%)			
	Protein	Starch	Soluble Sugars	Fat
S 29	11.3	66.3	1.3	3.8
SAR 1	6.7	68.5	1.2	3.5
DKV 3	8.5	65.3	0.9	2.8
CSH 1	9.3	66.7	1.3	3.7
IS 158	11.5	69.0	1.1	3.1
SPH 225	10.3	65.4	1.1	3.3
SPV 475	9.9	69.3	1.1	2.8
CSH 8	10.1	65.8	1.2	3.6
ET 3491	13.4	63.7	1.1	3.5
M 35-1	9.4	66.2	1.1	3.2
Mean	10.0	66.6	1.1	3.3
SE ±	0.57	0.57	0.04	0.12

Table 2 : Endosperm texture and dehulling characters of sorghum using a Tangential Abrasive Dehulling Device

Cultivar	Corneous-ness	Grain Hard-ness (kg/sq.cm)	Recovery (%)			
			Endosperm	Brokens	Total	Loss due to dehulling
S 29	1	7.0	87.5	0.5	88.0	12.0
SAR 1	1	5.4	67.0	13.2	80.2	19.8
DKV 3	1	8.1	93.0	0.7	93.7	6.3
CSH 1	3	8.8	85.0	4.6	89.6	10.4
IS 158	3	6.9	80.0	4.9	84.9	15.1
SPH 225	3	8.0	72.0	8.4	80.4	19.6
SPV 475	4	7.8	84.0	7.1	91.1	8.9
CSH 8	4	7.1	63.5	2.3	65.8	34.2
ET 3491	4	6.3	67.0	12.8	79.8	20.2
M 35-1	3	7.3	87.0	2.1	89.1	10.9
Mean	2.7	7.3	78.6	5.7	84.3	15.7
SE ±	0.40	0.31	3.28	1.47	2.46	2.57

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

Table 3 : Endosperm texture and dehulling characters of sorghum cultivars using a barley pearler

Cultivar	Corneous-ness	Recovery (%)			
		Endosperm	Brokens	Total	Loss by Dehulling
S 29	1	84.5	0.5	85.0	15.0
SAR 1	1	67.6	12.0	79.6	20.4
DKV 3	1	87.6	1.0	88.6	11.4
CSH 1	3	71.8	9.7	81.5	18.5
SPH 225	3	56.8	19.8	76.6	23.4
IS 158	3	71.2	7.2	78.4	21.6
SPV 475	4	78.1	8.3	86.4	13.6
CSH 8	4	51.4	19.9	71.3	28.7
ET 3491	4	52.0	19.2	71.2	28.8
M 35-1	4	69.6	6.2	75.8	24.2
Mean	2.7	69.1	10.4	79.4	20.6
SE ±	0.40	3.99	2.30	1.90	1.90

Dehulling was done using 100g grains for 2 min 15 sec in a Scott barley pearler

Porridge quality

Porridge was prepared by cooking 10 g of flour of dehulled grains with 50 ml hot distilled water for 7 minutes over a hot plate maintained at 275°C. The porridge consistency was evaluated by 4 panelists (Table 4) on scale of 1-4 where 1 is poor and 4 is good. The porridge quality ranged from 1.0 (IS 158) to 3.6 (DKV3). Textural measurement of porridge was done in duplicate with an Instron food testing instrument equipped with a back extrusion cell and fitted with a 20 kg compression cell. The values of initial and final forces are given (Table 4).

Dough quality

Textural measurement of dough was done in triplicate with the Instron food testing instrument equipped with a back extrusion cell and fitted with a 100 kg compression cell. Initial and final force (Kg), slope and work done (Joules) were recorded. Variations were observed for initial and final forces, work done and slope of the curve for the 10 cultivars tested. Flours of S 29, DKV3, SPH 225, and ET 3491 produced good quality dough (Table 5).

The correlation coefficients between grain hardness, endosperm texture, and dehulling characters and porridge quality and dough characters were determined. The corneousness of endosperm was significantly correlated with endosperm recovery (-0.68), when dehulled in a barley pearler. The dehulling characters as evaluated by TADD did not show any relationship with endosperm texture and hardness of grain for the cultivars tested (Table 6). The correlation coefficients between corneousness score and Instron readings of

Table 4 : Porridge quality of sorghum cultivars

Cultivar	Porridge quality		
	Score	Instron	
	Dehulled flour	Initial force	Final force (kg)
S 29	3.4	11.4	12.2
SAR 1	2.5	14.8	14.8
DKV 3	3.6	11.1	13.0
CSH 1	2.2	-	-
IS 158	1.0	2.6	4.7
SPH 225	3.0	11.7	15.5
SPV 475	3.0	14.3	15.8
CSH 8	2.3	15.8	17.9
ET 3491	3.0	14.4	16.0
M 35-1	2.6	12.7	14.3
Mean	2.6	12.1	13.8
SE ±	0.25	1.24	1.20

Porridge quality was evaluated by 4 members on a 1-4 score and 1 is Poor and 4 is Excellent

Table 5 : Textural properties of sorghum dough (INSTRON)

Cultivar	Initial force (Kg)	Final force (Kg)	Work done (joules)	Slope of the curve
S 29	19.0	28.0	1.72	0.42
SAR 1	11.3	18.3	1.21	0.26
DKV 3	25.7	39.3	2.41	0.48
CSH 1	22.3	34.0	2.11	0.41
IS 158	39.7	59.3	3.43	0.70
SPH 225	23.5	38.2	2.32	0.52
SPV 475	18.7	27.3	1.73	0.30
CSH 8	15.0	21.7	1.34	0.23
ET 3491	17.7	28.3	1.70	0.40
M 35-1	13.5	21.0	1.35	0.27
Mean	20.6	31.7	1.93	0.40
SE ±	2.55	3.81	0.21	0.05

Dough was made by mixing 50 g flour with 40 ml water; dough was divided into three equal parts and back extrusion pattern was measured on Instron fitted with 0-100 kg load cell.

Table 6 : Simple correlation coefficients between endosperm texture, and grain hardness with other characters in sorghum (n=10).

Parameters	Corneous score of endosprem	Grain hardness
Dehulling Characters		
Endosperm Recovery (BP)	-0.68*	0.30
Brokens (BP)	0.62	-0.20
Endosperm Recovery (TADD)	-0.37	0.58
Brokens (TADD)	0.20	-0.54
Porridge Quality		
Porridge Quality	0.33	-0.14
Initial Force(BP)	0.02	0.32
Final force	0.02	0.31
Dough Characters (Instron)		
Slope	-0.10	0.22
Area of peak	-	0.34
Work done	-	0.34

TADD: Tangential Arasive Dehulling Device

BP : Barley pearler

*Significant at 5% per cent level

dough, porridge quality of whole flour and dehulled grain flours were low and statistically insignificant.

Physical characteristics of isolated starch

Starch was isolated (Schoch's method) from grains of four cultivars DKV 3, CSH 8, SAR 1, and IS 158. These comprises of corneous and floury endosperm types and a waxy line. Solubility and swelling power at 60°C, 70°C, 80°C, and 90°C were studied. The swelling power of starch was low at 60, 70 and 80°C and waxy line (IS 158) had higher swelling power (Table 7). At 90°C, CSH 8 showed lower value and waxy line had higher value. The solubility was comparatively low for IS 158 (waxy). DKV 3 had the highest solubility at 90°C. The swelling power of the waxy line was considerably higher than the normal cultivars at all other temparatures.

Diastatic activity

(a) Flour and Dough:

Diastatic activity of flour and dough at initial (0 min), 30 and 60 min after dough making was measured on grain samples of 12 cultivars. Maltose units released per 10 g flour ranged from 106 to 254 with a mean of 195 for flour; for dough at initial period (0 min) it ranged from 56 to 155 with a mean of 112; for dough at 30 min, from 85 to 164 with a mean of 140; and at 60 min, it ranged from 104 to 201 with a mean of 163. Data indicated that maltose concentration of the dough gradually increased with the increase of time (Table 8).

(b) Malting studies:

The method for the determination of diastatic activity in relation

Table 7 : Swelling power and solubility of isolated starch.

Cultivar	Swelling power				Solubility (%)			
	60°C	70°	80°C	90°C	60°C	70°C	80°C	90°C
DKV 3	2.1	9.1	10.7	16.5	1.9	8.0	12.8	31.6
CSH 8	2.6	9.5	10.9	13.9	1.6	7.6	14.8	27.6
SAR 1	3.0	10.0	11.4	17.6	1.5	5.7	10.2	28.6
IS 158	4.5	18.2	25.5	28.4	3.0	9.2	14.4	21.3

Table 8 : Diastatic activity of sorghum dough

Cultivar	mg maltose released. 10 g^{-1} flour			
	Flour	Time after dough preparation min		
		0	30	60
SPH 265	151	89	116	143
SPH 225	160	101	125	143
Tetron	164	113	137	163
ET 187	174	95	132	148
SPH 475	192	113	147	165
IS 12611	210	135	164	201
P 721	213	112	139	156
E 35-1	222	116	164	171
S 29	244	117	124	148
Safra	251	155	189	225
ET 3491	254	138	156	188
M 35-1	106	56	85	104
Mean	195	112	140	163
SE ±	13.14	7.37	7.79	9.03

Dough was made by mixing 50 g of flour with 40 ml of water.

to malting was standardized. Grain samples from 20 cultivars comprising soft and hard endosperm types, red pericarp, high tannin lines and local market samples were germinated on moist cotton kept in petri dishes in an incubator at 30°C for 96 h. The growing vegetative parts (roots and shoots) were removed. The length and weight of growing parts were measured. The germinated (sprouted) seeds were freeze-dried and ground to fine flour. Diastatic activity was measured in flour samples. Maltose released per 100 g of sprouted grain ranged from 0.4 to 2.0 g with a mean of 1.1 (Table 9). Saffra showed the highest activity, followed by other cultivars, IS 7055, IS 14384, ET 3491, SPV 472 and Market 1.

Water retention capacity and starch damage

A total of 35 samples representing a wide range of grain characteristics were analyzed for water retention capacity (WRC) and starch damage. The water retention capacity of flours ranged from 118.2 to 133.5 with a mean of 145.7 and starch damage (%) ranged from 8.9 to 15.2 with a mean of 12.3. The WRC was significantly correlated with starch damage % ($r=0.73$, $P<0.01$).

Nutritional and food quality of elite cultivars

The proximate composition of grains of 15 elite cultivars was determined (Table 10). These lines include released and pre-release cultivars including hybrids developed at ICRISAT center and were grown during 1984 post-rainy season. Protein content of hybrids in general were higher, including that of SPH 221. Fat content of SPV 386, SPV 387, DKV 3, and all the five pre-release hybrids was 4.9%

Table 9 : Diastatic activity in sprouted sorghum grains.

Cultivar	Diastastic activity[a]
SAR 1	0.4
Lulu dwarf	0.5
M 24981	0.7
SPV 104	0.7
SPV 351	0.7
N 13	0.8
DKV 3	0.9
SPV 475	1.1
M 24959	1.2
CO 4	1.2
SPV 386	1.2
WS 1297	1.3
Dobbs	1.3
Market 1	1.5
ET 3491	1.5
SPV 472	1.5
IS 14384	1.6
IS 7055	1.8
Saffra	2.0
M 35-1	0.6
Mean	1.1
SE ±	0.10

Grains were sprouted for 96 h.

[a] g maltose. 100 g^{-1} material.

Values are based on two determinations.

Table 10 : Proximate composition and porridge quality of elite cultivars.

Cultivar	%						Porridge quality score
	Protein	Fat	Soluble sugars	Starch	Ash	Crude fiber	
SPV 351	12.0	4.7	1.1	73.1	1.6	2.3	1.4
SPV 386	11.6	4.9	1.3	69.2	1.6	2.5	1.0
SPV 475	10.8	3.4	1.2	78.0	1.5	2.0	1.4
SPV 615	11.6	3.8	1.1	72.4	1.7	2.7	1.6
SPV 387	10.9	5.1	1.1	74.8	1.6	2.1	2.6
SAR 1	7.6	4.0	1.0	76.5	1.7	1.7	2.4
DKV 3	9.8	4.9	0.9	73.0	1.5	2.3	2.6
PM 11344	10.3	4.3	1.0	74.8	1.5	1.9	2.4
SPH 221	10.6	3.5	1.2	79.2	1.6	2.1	3.0
SPH 296	12.0	3.5	1.1	75.9	1.7	2.2	2.6
MA9 x MR819	12.3	5.3	1.2	71.6	1.7	2.1	2.8
MA10 x MR849	9.7	4.9	1.1	75.1	1.6	2.2	2.6
MA10 x MR862	13.9	4.9	1.2	69.2	1.7	2.5	2.4
MA12 x MR822	10.6	4.9	0.9	70.3	1.4	2.0	2.4
MA12 x MR855	9.6	5.0	1.2	72.8	1.6	2.2	2.4
Mean	10.9	4.5	1.1	73.7	1.6	2.2	2.2
SE ±	0.38	0.17	0.03	0.78	0.02	0.06	0.15

Values are means of three determinations; proximate composition given on moisture free basis.

Porridge quality was evaluated by four members on a score of 1-4, where 1 is Poor and 4 is Excellent and above. Total soluble sugars content showed variation from 0.9 to 1.3%; starch content of the cultivars ranaged from 69.2 to 79.2%; SPH 221 had higher starch content. Ash and crude fiber contents did not show variation among the cultivars.

Fifteen elite cultivars were evaluated for porridge quality by 4 panelists. The porridge quality score ranged from 1.0 (SPV 386) to 3.0 (SPH 221) (Table 10).

Amino acid composition of 15 cultivars did not vary appreciably (Table 11). However, PM 11344 and MA 2 x MR 855 showed moderately high protein and lysine contents. Though SAR 1 had lysine content of more than 3%, its protein content was low (Table 11).

Dough and roti quality, and porridge quality were evaluated for 4 cultivars, CSV 11, CSH 11, PM 11344 and SAR 1. Dough rolling quality of these cultivars was good. Roti quality as evaluated by a taste panel was also good for these cultivars (Table 12). Porridge consistency was good for SAR 1, CSH 11, and PM 11344 while it was medium for CSV 11.

Table 11 : Amino acid composition of sorghum grains (g. 100 g^{-1} protein)

AMINO ACID	SPH 221	SPH 296	SPV 475	SPV 615	SPV 351	SPV 386	SVP 387	SAR 1	DKV3	PM 11344	MA 9 x MR 819	MA 10 x MR 849	MA 10 x MR 862	MA 12 x MR 822	MA 12 x MR 865
Aspartic acid	6.95	6.92	7.19	7.13	7.41	7.49	7.54	7.19	7.41	7.21	7.17	7.15	7.28	7.36	7.02
Threonine	3.22	3.00	3.09	3.18	3.22	3.39	3.19	3.41	3.26	3.12	3.14	3.11	3.03	3.15	3.04
Serine	4.27	4.21	4.10	4.27	4.28	4.28	4.35	4.38	4.70	4.28	4.13	4.04	4.13	4.25	3.98
Glutamic acid	19.78	19.44	19.43	19.71	20.22	20.05	19.50	19.56	9.65	19.57	19.02	19.30	19.33	19.58	19.26
Proline	8.05	8.00	7.91	8.10	8.16	8.22	7.87	8.10	8.26	7.99	7.59	8.13	8.28	8.09	8.02
Glycine	3.38	3.14	3.27	3.22	3.19	3.45	3.32	3.61	3.38	3.22	3.14	3.18	3.00	3.21	3.29
Alanine	8.97	9.01	8.91	8.91	8.90	8.79	8.91	8.45	9.04	8.73	8.74	8.56	8.50	8.41	8.24
Cystine	1.11	1.15	1.09	1.08	1.10	1.17	1.18	1.20	1.31	1.28	1.27	1.18	1.29	1.07	1.13
Valine	5.15	5.06	5.03	5.08	5.07	4.96	5.00	5.11	5.19	5.18	5.11	4.89	4.82	4.92	4.71
Methionine	1.27	1.23	1.29	1.34	1.25	1.29	1.15	1.14	1.41	1.12	1.15	1.28	1.18	1.30	1.34
Isoleucine	4.03	3.97	3.93	3.85	3.79	3.76	3.87	3.79	3.85	3.74	3.54	3.75	3.66	3.72	3.80
Leucine	11.62	11.71	11.87	11.66	11.81	11.85	11.71	11.19	11.96	11.19	11.28	11.41	11.47	11.34	11.28
Tyrosine	4.51	4.38	4.32	4.43	4.06	4.19	4.42	4.25	4.33	4.25	4.05	·4.23	4.05	4.17	4.33
Phenylalanine	5.36	5.38	5.26	5.26	4.21	5.22	5.35	5.30	5.34	5.05	5.03	5.16	5.00	5.00	5.03
Histidine	2.69	2.50	2.55	2.58	2.71	2.65	2.61	3.17	2.78	2.74	2.44	2.56	2.44	2.48	2.60
Lysine	2.73	2.55	2.63	2.68	2.57	2.56	2.81	3.25	2.58	2.89	2.59	2.59	2.39	2.46	2.88
Arginine	4.79	4.64	4.65	4.65	4.56	4.68	5.05	4.51	4.67	4.84	4.88	4.73	4.35	4.35	5.02
Total	97.88	96.29	96.52	97.13	96.51	98.00	97.83	97.61	99.12	96.40	94.19	95.25	94.20	94.06	94.97

Table 12 : Food Quality of elite sorghum cultivars.

Factors	CSV 11	CSH 11	PM 11344	SAR 1	M 35-1 (Check)	Mean	SE ±
Dough							
Water for dough (ml/100 g flour)	92	86	85	83	80	85.2	1.98
Rolling quality	good	good	good	good	good		
Kneading quality	good	good	good	good	good		
***Roti* (taste panel evaluation)[a]**							
Color and appearance	3.1	3.3	3.2	3.0	3.9	3.3	0.16
Texture	2.7	2.6	2.5	2.5	3.7	2.8	0.23
Flavor	2.6	2.9	2.7	2.7	3.0	2.8	0.07
Taste	2.6	2.9	2.9	2.6	3.3	2.9	0.17
Genaral acceptability	2.7	2.8	2.9	2.5	3.4	2.9	0.13
Mean	2.7	2.9	2.7	2.8	3.5	2.9	0.15
Porridge consistency[b]	2.8	4.0	4.5	4.0	4.8	4.0	0.34

[a]*Roti* score : 1 - Poor; 4 - Excellent

[b]Porridge score : 1 - Poor; 5 - Excellent

PEARL MILLET

Project No. : M-132 (85) IC

Project title : Evaluation of food quality characters and physicochemical properties of pearl millet.

Objectives

a) Standardize the methods of preperation of pearl millet foods (of India and African countries) and evaluate the food quality of selected cultivars.

b) Determine the physicochemical properties of selected pearl millet cultivars.

c) Determine the relationship between physicochemical, structural and processing charactristics of pearl millet grain and food quality.

Fifteen pearl millet cultivars representing diverse geographical origin were grown at Bhavanisagar during the 1982 rainy season (June-September). Details of the cultivars are given in Table 13.

Dehulling quality

Dehulling was done by the traditional method of hand pounding using mortar and pestle, and mechanically using a barley pearler and a Tangential Abrasive Dehulling Device (TADD).

For traditional dehulling, 200 g grains were tempered using required quantities of water (by sprinkling while pounding), and volume of water added was noted. Number of strokes needed to dehull, time taken, recoveries of endosperm (dehulled grain), brokens and husk were recorded. Wide variations were observed for the quantities of water added to temper the grain for dehulling. Grains of cultivars DSA 74, Souna, Togo, Nigerian composite (NC), SAD 448, Mossi Local and BJ 104 required longer time to dehull by the traditional method. Sanio and Fakiayabad required less time to dehull (Table 14). DSA 74, Souna, Togo and Mossi Local required more number of stroks to dehull the grain. Sanio and Fakiayabad required less number of strokes for dehulling. Mossi Local, BK 560, and WC C75 gave higher endosperm recovery and K 13, and NBB gave lower endosperm recovery. Recovery of husk and broken fractions for the 15 cultivars showed variation.

Barley pearler (vertical movement of carborundum wheel) was used to compare the dehulling quality of cultivars. Grains of each cultivars were dehulled for different times. Optimal dehulling was judged by a staining technique using methylene blue and eosine-Y. Grains dehulled

Table 13 : Origin and physical characters of the pearl millet cultivars.

Cultivar	Origin	1000 grain weight (g)	Grain hardness[a] (kg/sq.cm)
WC C75	ICRISAT	7.99	3.4
ICMS 7703	ICRISAT	8.07	3.1
BK 560	India	7.53	2.5
BJ 104	India	6.63	2.5
Fakiayabad	Sudan	11.28	2.6
K 13	Sudan	8.04	2.5
Sanio	Niger	11.67	3.0
CIVT II	Niger	9.61	3.4
NC	Niger	8.63	3.3
Mossi Local	Burkina Faso	9.90	3.6
NBB	Mali	10.87	2.7
DSA 74	Ghana	13.61	3.8
Togo	Benin/Ghana	11.00	3.6
Souna	Senegal	7.72	3.8
SAD 448	Malawi	8.47	3.0
Mean		9.40	3.1
SE ±		0.52	0.13

[a]Means of 20 grains

Table 14 : Dehulling quality of pearl millet grains evaluated by traditional method

Cultivar	Processing characteristics[a]				Recovery (%)			
	Water added ml	Number of strokes	Time Min	Sec	Endo-sperm	Brokens	Husk	Total
WC C75	22.5	389	4	30	75.3	11.9	11.7	98.9
IOMS 7703	23.0	371	4	45	68.7	13.9	16.0	98.6
BK 560	19.0	333	4	45	77.1	9.9	9.7	96.7
BJ 104	19.5	393	5	00	73.3	15.6	9.7	98.6
Fakiayad	22.5	288	3	40	68.8	15.6	13.2	97.6
K 13	29.5	364	4	40	63.6	17.0	16.6	97.2
Sanio	21.5	293	3	50	68.2	15.0	13.1	96.3
CIVT II	21.5	394	4	40	72.0	12.0	13.7	97.7
NC	19.0	397	5	00	69.5	13.2	13.7	96.4
Mossi Local	24.0	441	5	50	77.2	10.3	10.3	98.8
NBB	20.0	336	4	25	64.1	16.5	13.9	94.5
DSA 74	27.5	456	6	10	70.3	12.7	12.7	95.7
Togo	22.5	481	5	50	66.7	14.7	13.7	95.1
Souna	29.5	538	5	00	56.9	19.2	17.8	93.9
SAD 448	18.5	411	5	15	71.7	14.3	11.5	97.5
MEAN	22.7	292			69.6	14.3	13.2	-
SE ±	0.93	18			1.40	0.71	0.62	

Each value is the mean of two determinations.

[a] 200 g lots were processed by the traditional method.

for different times were stained. Endosperm stains light pink with the stain; pericarp stains bluish green and germ stains dark blue. More pink area on the grain surface indicates better dehulling. Fakiayabad gave the lowest recovery with more brokens and husk (Table 15). Other cultivars did not vary appreciably in their recoveries. However, bold grain types, souna, NC and SAD 448 required more time for dehulling. CIVT II required comparitively less time for dehulling.

In another study, grains of nine cultivars were dehulled in a barley pealer for uniform time (2 min 50 sec, which is the mean dehulling time for the 15 cultivars). SAD 448 and Souna gave higher endosperm recoveries and Fakiayabad gave lowest recovery (Table 16). Husk content was higher for CIVT II and lower for Souna and Fakiayabad.

Dehulling by TADD (horizontal movement of carborandum wheel) showed large variation among the cultivars, except for Fakiayabad, a soft grain type which yielded low recovery. Grain size varied considerably in millet; the grains were sieved through 6/64" sieve and those retained on the sieve were dehulled. Cultivars did not appreciably vary for dehulling recovery except for Fakiayabad. Cultivars SAD 448, Mossi local, EJ 104, Souna, BK 560, DSA 74, and NC gave higher recoveries (Table 17). The present studies indicated that mechanical dehulling is advantageous over traditional method.

Dehulling quality in relation to nutrient composition

The dehulling quality has to be judged not only with endosperm recovery, but also with the extent of retention of nutrients in the grain even after dehulling.

Table 15 : Optimum time for dehulling of pearl millet using a barley pearler

Cultivar	Optimum time[a]		Recovery(%)			
	Min	Sec	Endosperm	Brokens	Husk	Total
WC C75	2	45	86.2	1.9	11.5	99.6
Fakiayabad	2	45	77.6	7.5	13.8	98.9
CIVT II	2	05	87.4	1.2	12.0	100.6
NC	3	00	86.9	1.6	10.9	99.4
Mossi local	2	25	88.5	1.4	10.8	100.7
DSA 74	2	20	86.6	1.2	11.3	99.1
Togo	2	30	87.6	1.8	10.8	100.2
Souna	3	15	87.7	1.6	9.8	99.1
SAD 448	3	10	88.7	1.8	9.0	99.5
MEAN	-	-	86.4	2.2	11.1	99.7
SE ±	-	-	1.13	0.67	0.45	-

Each value is a mean of two determinations.

[a]Time to dehull on 100 g sample and completion of dehulling was tested by "staining" method.

Table 16 : Dehulling quality of pearl millet grains evaluated by barley pearler.

Cultivar	Recovery (%)			
	Endosperm	Brokens	Husk	Total
WC C75	86.8	0.68	11.9	99.4
Fakiayabad	76.5	7.10	15.6	99.2
CIVT II	86.6	0.69	11.9	99.2
NC	86.9	0.49	11.9	99.3
Mossi local	86.0	1.59	12.4	99.8
DSA 74	83.2	1.54	14.4	99.1
Togo	84.8	1.89	12.9	99.6
Souna	89.1	0.67	9.0	99.8
SAD 448	89.5	0.57	9.2	99.3
MEAN	85.5	1.69	12.1	-
SE ±	1.30	0.70	0.71	-

All samples were dehulled for 2 min 50 sec

Values are based on 100 g sample.

Each value is a mean of 2 determinations.

Table 17 : Dehulling quality of pearl millet grains evaluated by TADD

Cultivar	Recovery (%)			
	Grains (unsieved)[a]		Grains retained on 6/64" sieve[b]	
	Endosperm	Brokens	Endosperm	Brokens
WC C75	86.2	1.4	86.9	1.2
ICMS 7703	86.2	0.7	87.4	0.5
BK 560	-	-	87.8	1.3
BJ 104	89.3	0.4	88.9	1.3
Fakiayabad	77.1	2.1	80.5	0.1
K 13	85.5	1.3	85.6	2.0
Sanio	-	-	82.2	1.8
CIVT II	85.5	0.6	86.4	0.6
NC	86.6	0.4	87.4	0.2
Mossi Local	87.2	1.2	89.1	0.6
NBB	-	-	81.4	2.8
DSA 74	85.8	2.5	87.4	1.1
Togo	85.2	1.6	85.8	1.4
Souna	86.6	1.2	88.4	0.6
SAD 448	88.3	0.6	89.5	0.5
MEAN	85.8	1.2	86.8	1.1
SE ±	0.86	0.19	0.73	0.19

20 grams sample was dehulled for 4 min in TADD.

[a]Values are based on duplicate determinations.

[b]Values are based on single determination.

A comparison of average values obtained from nine cultivars for physical and chemical characters of grains due to dehulling are given in Table 18. Reduction in crude fiber was upto 30% due to traditional method and upto 50% due to barley pearler and TADD. Sugar content was also reduced considerably. Protein loss was not appreciable due to dehulling.

Thousand grains weight of dehulled grain was lower in hard grains types like SAD 448 (Table 19). The variation in 1000-grain weight for the cultivars was not appreciable due to dehulling. However, grains of SAD 448 showed lower values due to dehulling.

Chemical composition was determined in whole and dehulled grains. Losses in nutrients by different dehulling methods were compared. Loss was expressed as $g.100\ g^{-1}$ dehulled material and on $mg.grain^{-1}$ basis. A considerable reduction in crude fiber and ash contents was observed due to dehulling, indicating that these nutrients are lost in husk. Sugar loss was comparatively higher in the traditional dehulling as compared to barley pearler and TADD. Protein, starch and fat loss was also higher due to traditional method. It is very difficult to judge the superiority of cultivars based on loss of nutrients due to dehulling. However, nutrient losses are nearly similar in all the cultivars by traditional method (Table 20). Souna and SAD 448 exhibited lower losses in majority of the nutrients by barley pearler. In TADD, DSA 74 performed better than other cultivars with regard to nutrient retention. The data suggests that the nutrients are unevenly distributed in the anatomical parts of the grains of different cultivars.

Table 18 : Influence of dehulling on physicochemical characterstics of pearl millet.

Physicochemical characterstics	Whole grain	Dehulled grain		
		Traditional	Barley pearler	TADD
1000 grain wt(g)	9.80	8.88	8.82	9.11
Protein (%)	14.2	13.7	13.1	13.3
mg. grain^{-1}	1.4	1.2	1.1	1.2
Sugars (%)	1.73	1.15	1.33	1.30
mg. grain^{-1}	0.17	0.10	0.12	0.12
Starch (%)	76.7	81.8	82.4	80.7
mg. grain^{-1}	7.6	7.3	7.3	7.4
Fat (%)	5.99	5.24	5.47	5.16
mg. grain^{-1}	0.59	0.47	0.48	0.47
Ash (%)	1.89	1.36	1.32	1.38
mg. grain^{-1}	0.18	0.12	0.12	0.13
Crude fiber (%)	1.54	1.10	0.86	0.83
mg. grain^{-1}	0.15	0.10	0.08	0.08

Values are based on 9 cultivars

Values for chemical constituents are given on dry weight basis

Table 19 : Effect of dehulling on 1000 grain weight in pearl millet.

Cultivar	1000 grain weight (g)			
	Whole grain	Dehulling method		
		Traditional	Barley pearler	TADD
WC C75	7.99	7.48	7.21	7.04
Fakiayabad	11.28	9.97	10.09	10.57
CIVT II	9.61	8.91	8.43	8.29
NC	8.63	7.48	8.59	8.00
Mossi Local	9.90	9.30	9.15	9.55
DSA 74	13.61	10.33	11.56	11.95
Togo	11.01	10.69	9.26	10.48
Souna	7.72	7.35	6.80	6.37
SAD 448	8.47	6.87	6.72	7.61
MEAN	9.80	8.88	8.82	9.11
SE ±	0.61	0.62	0.53	0.51

Table 20 : Reduction in protein (PR), fat (FA) ash (AS), soluble sugars (SU) starch (ST), and crude fiber (FI) contents due to different methods dehulling in pearl millet (g.100 g^{-1} basis)

Cultivar	Per cent reduction																	
	Traditional						Barley pearler						TADD					
	PR	FA	AS	SU	ST	FI	PR	FA	AS	SU	ST	FI	PR	FA	AS	SU	ST	FI
WC C75	27	37	51	31	21	39	19	25	46	4	6	56	24	31	45	12	8	54
Fakiayabad	32	41	44	47	27	53	35	33	45	44	16	56	25	30	36	38	17	59
CIVT II	28	35	51	52	21	48	15	18	45	29	5	52	17	26	45	34	9	55
NC	33	38	51	63	25	48	17	17	42	45	8	51	18	26	27	47	12	55
Mossi Local	26	27	46	63	17	35	22	18	40	47	8	52	20	19	35	43	8	56
DSA 74	31	37	47	40	23	57	23	24	40	28	8	55	18	23	27	24	7	52
Togo	35	43	49	44	29	52	22	22	43	37	10	53	19	32	35	38	10	50
Souna	47	58	63	70	40	66	14	21	31	23	6	46	14	28	42	36	9	54
SAD 448	31	34	46	56	26	44	19	21	31	49	7	52	20	35	34	35	9	53
MEAN	32	39	50	52	25	49	21	22	40	34	8	53	19	28	36	34	9	54
SE ±	2	3	2	4	2	3	2	2	2	5	1	1	1	2	2	4	1	1

When loss of nutrients are expressed as $mg.grain^{-1}$, it was low in WC C75 except for ash content, by traditional method (Table 21). Considering the other two mechanical methods, Souna, Fakiayabad and Mossi local showed more retention of nutrients in the dehulled grains. Grain recovery for Souna and Mossi local was better and they can be regarded as well suited for mechanical dehulling.

Nitrogen distribution in whole grain, traditionally-dehulled grain and grains dehulled in a barley pearler was determined by Landry-Moreaux procedure using the cultivar Togo. Whole grain contained 24% of albumin- globulin and 38% prolamines (Table 22). Traditional dehulling resulted in substantial loss of albumin-globulin fraction whereas, in mechanical dehulling the loss was much less. The loss was reflected in the distribution of this fraction in husk. Prolamine fraction was present in endosperm and was not lost as compared to albumin-globulin fraction of the grains. Distribution of other fractions did not vary appreciably.

Porridge quality

To standardize the methodology for the preparation of thick porridge, varying quantities of flour of WC C 75 was cooked for different periods from 1 to 15 min with an interval of 1 min. Varying quantities of water (40, 45, 48, and 50 ml) was also used. Based on the data, cooking 10 g flour with 50 ml water for 7 minutes was followed for testing the cultivars. Porridges made with dehulled flour were evaluated by 4 members (Table 23). Porridge quality was subjectively evaluated for consistency using a score of 1-5, where 1 is poor and 5 is excellent. Porridge quality of the cultivars DSA 74, SAD 448, and Fakiayabad were rated high.

Table 21 : Reduction in protein (PR), fat (FA), ash (AS), soluble sugars (SU) starch (ST) and crude fiber (FI) contents of pearl millet due to different dehulling methods (mg.grain^{-1} basis)

Cultivar	Per cent reduction																	
	Traditional						Barley pearler						TADD					
	PR	FA	AS	SU	ST	FI	PR	FA	AS	SU	ST	FI	PR	FA	AS	SU	ST	FI
WC C75	10	21	39	13	2	25	16	22	45	0	3	54	24	29	44	9	6	54
Fakiyabad	7	16	37	39	2	36	16	17	44	28	4	52	16	25	44	33	9	56
CIVT II	0	13	17	22	7	30	25	21	36	35	21	49	8	15	22	25	-	50
NC	17	22	39	53	7	35	5	5	34	37	6	43	13	20	35	48	7	52
Mossi Local	9	10	33	55	1	21	16	12	36	43	1	35	11	10	28	39	3	45
CSA 74	26	32	43	36	18	53	21	22	38	28	9	54	16	21	25	22	8	51
Togo	5	17	26	18	2	31	22	23	42	38	12	54	9	23	26	30	1	45
Souna	12	29	38	49	0	43	6	4	16	3	17	33	9	8	26	18	16	41
SAD 448	28	26	39	50	15	37	29	30	39	41	16	57	19	25	33	34	7	52
MEAN	13	21	35	37	6	35	17	17	37	28	10	48	14	20	31	29	6	50
SE ±	3	2	3	5	2	3	3	3	3	5	2	3	2	2	3	4	2	2

Table 22 : Nitrogen distribution in whole grain and dehulled grain fractions of Togo cultivar.

Grain fractions	Dehulling recovery (%)	Protein (%)	Per cent of total nitrogen — Protein fractions I	II	III	IV	V
Whole grain	-	11.7	24.3	38.0	3.6	4.2	14.1
Dehulled grain-Traditional method							
Endosperm	66.7	10.7	11.1	29.4	2.4	2.9	9.7
Husk	13.7	18.8	5.1	1.7	0.2	0.5	2.0
Dehulled grain-Barley pealer							
Endosperm	84.8	10.5	17.2	35.6	3.4	3.7	13.3
Husk	12.9	20.1	5.7	1.6	0.2	0.5	1.1

fraction I : Albumins and globulins; II: Prolamines;

II : Cross-linked prolamines; IV: Glutelin-like; V: Glutelin

Table 23 : Porridge quality of pearl millet cultivars

Cultivar	Porridge score for dehulled grain flou	
	Traditional method	Barley pearler method
WC C75	4.7	3.0
ICMS 7703	4.0	3.5
BK 560	4.7	4.3
BJ 104	3.5	4.3
Fakiayabad	2.7	2.7
K 13	3.3	3.7
sanio	4.0	5.0
CIVT II	4.2	2.3
NC	4.0	3.7
Mossi Local	3.3	3.3
NBB	4.0	4.3
DSA 74	3.0	2.7
Togo	4.3	3.3
Souna	3.8	3.0
SAD 448	2.3	2.3
MEAN	3.7	3.4
SE ±	0.18	0.21

Porridge quality score: 1 - poor, 5 - excellent

Physical characteristics of flour

Physical characteristics such as swelling capacity, solubility (wt/wt and vol/vol) at 90°C and water-retention capacity of flour at room temparature were determined. Swelling capacity (vol/vol) at 90°C ranged from 5.7 to 8.6 with a mean of 6.8 (Table 24); solubility (vol/vol) ranged from 34.8 to 41.3 with a mean of 38.3; and water-retention capacity ranged from 116 to 145 with a mean of 137 . The water-retention capacity showed a significant negative association with swelling capacity (r=0.85, P<0.01) and did not show significant relationship with porridge quality. The correlation between swelling power and porridge quality (r=0.59, P<0.05) was significant (Table 25).

Swelling capacity of grains was also studied. Dehulling increased the swelling capacity of grains, both on volume as well as weight basis (Table 26). Similarly, swelling capacity (90°C for 1 h) was also determined for the flour obtained from whole grain and dehulled grain. Dehulling increased the flour swelling capacity (Table 27).

Starch properties

Starch was isolated from the grains of 15 cultivars. Viscosity of starch, swelling power and solubility at 60, 70, 80 and 90°C were determined. Viscosity of starch of DSA 74, Togo, Fakiayabad, Sanio and WC C75 was higher. Starch from BJ 104 had the least viscosity (Table 28). There were only minor variations for swelling power at 60, and 70°C. However, variations among the cultivars broadened at 80°C and at 90°C. Fakiayabad, NBB and Togo had higher swelling while WC C75 had the least swelling. Regarding solubility, minor variations were observed at 60 and 70°C. Significant

Table 24 : Physical characteristics of pearl millet flour

Cultivar	Swelling capacity[a] wt/wt	Swelling capacity[a] vol/vol	Solubility[b] at 90°C	Water retention capacity[c]
WC C75	7.8	6.1	39.6	143
ICMS 7703	8.0	6.1	36.3	140
BK 560	8.4	5.9	40.1	142
BJ 104	7.6	5.7	41.3	145
Fakiayabad	8.5	8.6	35.0	116
K 13	8.1	7.1	34.9	131
Sanio	8.5	7.0	34.8	132
CIVT II	7.9	7.0	40.8	137
NC	7.7	7.1	39.1	136
Mossi Local	7.8	7.1	38.1	137
NBB	8.0	7.1	36.2	136
DSA 74	7.7	6.9	41.0	138
Togo	8.1	7.0	39.8	138
Souna	8.0	6.5	39.8	139
SAD 448	8.1	7.3	37.1	143
MEAN	8.0	6.8	38.3	137
SE ±	0.07	0.18	0.61	1.83

Values are mean two determinations.

[a]one gram flour was treated with water at 90°C for 1 h and ratio expressed as before and after water treatment.

[b]The quantity of sclute obtained after evaporation.

[c]ml water retaind by 100 g flour.

Table 25 : Simple correlation coefficients between physical characteristics of the flour and porridge quality of pearl millet (n=15)

			r
Swelling capacity	vs	Solubility	-0.54*
"	vs	Water retention capacity (WRC)	-0.85**
"	vs	Porridge quality	0.59*
Solubility	vs	WRC	-0.65**
"	vs	Porridge quality	-0.32
WRC	vs	Porridge quality	-0.18

**Significant at 1% level.

* Significant at 5% level.

Table 26 : Swelling capacity of pearl millet grains as influenced by dehulling methods.

Cultivar	Whole grain		Dehulling method: Traditional		Barley pearler		TAAD	
	v/v	w/v	v/v	w/w	v/v	w/w	v/v	w/w
WC C75	2.9	2.7	4.3	3.4	4.1	3.3	3.9	3.1
ICMS 7703	2.8	2.5	--	---	4.0	3.1	3.7	3.0
BK 560	2.9	2.5	---	---	3.8	3.2	3.9	2.8
BJ 104	3.3	2.8	--	---	3.8	3.4	4.1	3.1
Fakiayabad	2.7	2.3	4.1	3.3	4.2	3.3	3.9	3.1
K 13	3.1	2.8	--	---	3.9	3.2	4.6	3.2
Sanio	3.2	2.6	---	---	3.8	3.2	3.8	3.1
CIVT II	2.7	2.4	3.8	3.0	3.9	2.9	3.7	2.8
NC	2.8	2.4	4.8	3.5	3.9	3.4	4.0	2.9
Mossi Local	3.2	2.6	4.4	3.3	3.9	3.3	4.0	3.2
NBB	2.9	2.5	---	---	3.6	2.9	3.3	2.6
DSA 74	2.9	2.3	4.1	3.6	3.9	3.0	3.6	2.9
Togo	2.5	2.3	3.8	3.2	3.8	3.0	3.9	3.0
Souna	2.9	2.6	4.3	3.3	3.8	2.9	3.9	3.2
SAD 448	3.0	2.6	4.1	3.5	3.8	3.3	3.9	3.1
MEAN	2.9	2.5	4.2	3.3	3.9	3.2	3.9	3.0
SE ±	0.06	0.04	0.10	0.06	0.04	0.05	0.07	0.05

Values are based on single determination.

One gram grain was treated with water at 90°C for 1 h and expressed as ratio for change in volume (v) and weight (w) before and after water treatment.

Table 27 : Swelling capacity(v/v) of whole grain and dehulled grain flours of pearl millet

Cultivar	Whole grain flour	Dehulled grain flour		
		Traditional	Barley pearler	TADD
WC C75	8.0	9.8	11.3	9.7
Fakiayabad	10.8	11.3	13.8	10.9
CIVT II	7.7	9.4	10.8	9.4
NC	8.0	10.1	11.7	10.1
Mossi Local	8.7	10.2	11.8	9.7
DSA 74	7.7	9.3	10.7	10.0
Togo	7.5	9.6	10.9	10.5
Souna	7.4	9.0	10.9	11.0
SAD 448	8.5	9.9	11.3	10.5
MEAN	9.0	9.8	11.5	10.2
SE ±	0.35	0.22	0.32	0.30

Each value is the mean of two determinations

Table 28 : Starch characters of pearl millet

Cultivar	Viscosity[a]	Swelling power				Solubility(%)			
		60° C	70° C	80° C	90° C	60° C	70° C	80° C	90° C
WC C 75	1.60	1.7	6.0	11.6	13.7	0.8	5.5	11.9	24.4
IOMS 7703	1.32	2.0	7.4	11.8	14.4	1.4	7.3	15.3	33.2
BK 560	1.73	1.7	5.9	12.9	15.5	1.0	5.8	13.9	25.4
BJ 104	1.09	2.2	6.5	12.1	14.7	1.1	6.3	12.9	27.7
Fakiayabad	1.61	1.8	7.0	12.7	17.2	0.9	5.1	16.5	28.6
K 13	1.43	2.3	6.0	9.9	15.6	1.1	6.5	11.8	30.6
Sanio	1.61	2.3	7.2	13.1	15.5	1.4	6.0	13.3	26.6
CIVT II	1.33	2.5	7.7	9.7	15.5	1.6	7.2	13.3	33.9
NC	1.46	2.5	7.7	9.9	15.0	1.1	7.3	12.5	32.9
Mossi Local	1.44	3.3	7.6	10.9	14.5	2.8	8.1	14.6	38.0
NBB	1.44	1.7	6.5	13.1	16.5	0.7	6.4	13.2	26.8
DSA 74	1.64	3.0	6.9	9.3	15.2	1.6	6.6	10.3	22.8
Togo	1.61	2.3	7.5	12.7	16.2	1.4	6.9	14.4	26.6
Souna	1.39	2.3	6.3	9.9	15.6	1.4	6.3	11.0	28.2
SAD 448	1.39	2.9	7.9	10.4	15.8	1.9	7.2	13.0	28.6
MEAN	1.47	2.3	6.9	11.3	15.4	1.4	6.6	13.2	29.0
SE ±	0.04	0.13	0.18	0.36	0.23	0.13	0.20	0.42	1.05

[a]Dynes/sq.cm

variation at 80°C has been observed for the cultivars, from 11.0 to 16.5%. Solubility increased to a higher magnitude at 90°C, for cultivars like CIVT II, NC, Mossi Local, and K 13.

Grain size studies

Studies on grain size variations have been done which will be helpful in assessing dehulling quality of grains.' Grain lots were sifted through various sieves and their distribution as retained on different sieves was expressed as percentage. In general, grains of the 15 cultivars studied were recovered in 6/64" and 1/12" sieves. Recoveries of DSA 74, Togo, Fakiayabad, Mossi local, Sanio and NBB were higher on 6/64" sieve (Table 29). Grains of ICMS 7703, and K 13, BJ 104, showed nearly equal quantities retained on 6/64" and 1/12" sieves. SAD 448 has nearly uniform grains which would have contributed to higher dehulling recoveries (Tables 16 and 17). NC, BJ 104, ICMS 7703, and K 13 had above 12% retention on 1/13" sieves. BJ 104, and SAD 448 also had smaller grains which were retained on 1/14" sieves and passed through 1/14".

In another study, grains of each cultivar were classified according to their size comprising of long, intermediate and round grains as judged by appearance, These grains were sifted through sieves and distribution was recorded. Round grains are generally larger and more than 57% was recovered on 6/64" sieve (Table 30). Long grains were distributed more on 1/12" sieve. Intermediate and long grains were not recovered in high quantities (<10%) on 7/64" sieve. Comparing the distribution of cultivars, MBH 110 and WC C75, both have distribution similar

Table 29 : Grain size distribution in pearl millet cultivars

Cultivar	Percent of whole grain					
	Retained on seive					thru
	8/64"	6/64"	1/12"	1/13"	1/14"	1/14"
WC C75	0.0	46.2	30.4	10.6	7.6	5.1
ICMS 7703	0.0	38.2	32.2	13.0	9.3	7.3
BK 560	0.0	42.3	28.3	11.9	8.9	8.4
BJ 104	0.0	28.6	29.0	15.2	13.6	13.7
Fakiayabad	7.0	77.4	9.6	2.6	1.6	1.3
K 13	0.0	39.2	33.3	12.5	8.3	6.7
Sanio	3.1	79.1	12.4	2.9	1.5	0.9
CIVT II	0.0	50.5	28.3	9.2	6.4	4.3
NC	0.0	42.6	31.7	18.0	8.0	5.9
Mossi Local	0.5	73.7	17.7	4.4	2.2	1.0
NBB	3.5	71.1	14.8	5.2	3.2	2.1
DSA 74	4.7	81.5	9.3	2.2	1.2	0.8
Togo	1.9	69.3	16.7	5.3	3.4	3.1
Souna	0.0	40.5	34.1	11.3	8.8	5.3
SAD 448	0.0	22.3	30.1	18.1	16.2	12.8
Mean	3.45	53.5	23.9	9.51	6.68	5.25
SE ±	0.92	5.29	2.46	1.46	1.21	1.09

Values based on 500 g grain lots used in seiving analysis and expressed as per cent retention on each sieve

Seives have round perforated mesh(inches, US specifications)

Values are mean of two determinations

Table 30 : Distribution of long, intermediate and round shaped grians in pearl millet cultivars.

Cultivar/ grain shape		Per cent retention on seive (inches)							thru
		8/64	7/64	6/64	1/12	1/13	1/14	1/15	1/15"
NELC	long	0.0	0.5	17.9	42.6	17.9	14.1	5.1	1.8
	intermediate	0.0	3.6	46.3	39.0	6.4	3.3	(1.1)	-
	round	0.1	10.9	57.8	25.9	3.2	(1.5)	-	-
SRC	long	0.0	0.4	15.4	44.3	18.5	14.0	4.9	1.7
	intermediate	0.0	2.3	41.1	45.3	7.3	3.0	(1.0)	-
	round	0.0	10.2	65.2	21.2	1.8	(1.4)	-	-
EGP	long	0.0	0.7	16.1	47.1	17.9	13.0	4.1	1.2
	intermediate	0.0	6.7	51.1	34.3	4.7	(2.6)	-	-
	round	0.6	19.7	60.3	16.3	1.9	(1.2)	-	-
MC	intermediate	0.2	9.1	57.9	27.5	3.5	(1.8)	-	-
	round	0.8	29.0	58.2	10.2	(1.7)	-	-	-
WC C75		0.0	5.9	52.9	32.2	5.4	2.4	(0.7)	-
MBH 110		0.1	9.2	45.3	30.7	7.4	4.5	(2.5)	-
Mean		0.14	8.3	45.0	32.0	8.0	7.8	4.7	1.6
SE ±		0.07	2.9	4.88	3.22	1.84	2.12	0.31	0.19

NELC : near elite composite; SRC : Serere composite;

EGP : early gene pool; MC : medium composite;

Values are mean of two determinations using 200 g samples each time, and expressed as percentage

Values in paranthesis indicate the grains passed through the respective seives.

to intermediate types and their distribution was recorded.

Physical characters of long, intermediate and round grain types were also determined and given in Table 31. One hundred grain weight and grain hardness were higher for round grains as compared to intermediate and long grains. Length/breadth (l/b) and length/thickness (l/t) ratio of long and intermediate were higher. Proportion of larger grains (as retained by 1/12" sieve) was higher in round grains. Bulk density of round grain was higher compared to intermediate types. However, long ones had nearly similar bulk densities of round grains.

Long, intermediate and round grains were dehulled using TADD. Intermediate gave higher dehulling recovery (Table 32). The recovery was lower in longer grains. WC C75 gave higher recovery as compared to MBH 110 (Table 32). Dehulling was also done at variable times using a barley pearler. Efficiency of dehulling was tested with dual staining technique, evaluated by two persons independently. Round types dehull better than long grains and less time was required to get satisfactory level of dehulling (Table 33). It appears to be difficult to dehull long grain types. Both WC C75 and MBH 110 could be dehulled in 3 minutes 45 sec in a barley pearler. Endosperm recovery was higher for WC C75 as compared to MBH 110.

Table 31 : Physical characters of pearl millet grains.

Cultivar grain shape	1000 grain wt (g)[a]	Grain hardness[b] (kg/sq.cm)	Grain dimensions[c] (mm) Length (l)	Breadth (b)	Thickness (t)	l/b	b/t	Retention per cent on 1/12" sieve[d]	Passed through 1/12" sieve[d]	Bulk density (ml/kg)[e]
NELC										
long	8.0	2.3	3.50	1.87	1.56	1.87	1.20	61.0	39.0	1167
inter	9.4	2.6	3.39	2.23	1.85	1.52	1.21	88.8	11.2	1147
round	10.6	2.7	3.31	2.44	2.02	1.36	1.21	94.8	5.3	1170
SRC										
long	8.0	2.4	3.78	2.03	1.70	1.86	1.19	60.2	39.8	1170
inter	10.2	2.6	3.39	2.25	1.98	1.51	1.14	88.7	11.3	1140
round	11.1	2.7	3.05	2.30	2.13	1.33	1.08	96.6	3.4	1173
EGP										
long	9.1	2.5	3.82	2.04	1.73	1.87	1.18	63.9	36.1	1160
inter	10.6	2.9	3.38	2.40	2.03	1.41	1.18	92.2	7.8	1147
round	12.1	2.9	3.22	2.50	2.17	1.29	1.15	96.8	3.2	1170
MC										
inter	11.1	2.7	3.40	2.30	2.02	1.48	1.14	94.7	5.3	1150
round	12.2	3.1	3.13	2.52	2.23	1.24	1.13	98.2	1.8	1177
WC C75	10.2	2.6	3.27	2.36	2.01	1.39	1.18	91.1	8.9	1160
MBH 110	10.4	2.9	3.02	2.41	2.19	1.25	1.10	85.2	14.8	1193
Mean	10.2	2.7	3.36	2.28	1.97	1.49	1.16	85.6	14.5	1163
SE ±	0.38	0.07	0.07	0.06	0.06	0.07	0.01	4.07	4.07	4.23

[a]Mean of 5 determinations

[b]Mean from 20 grains

[c]Mean from 50 grains

[d]Mean of 2 determinations.

[e]Mean of 6 determinations.

Table 32 : Dehulling quality of pearl millet grains of varying shapes

Cultivar	Grain shape	Grain hardness (kg/sq.cm)	Recovery(%)		
			Endosperm	Brokens	Loss
NELC	long	2.3	80.5	2.0	17.5
	intermediate	2.6	83.9	1.4	14.7
	round	2.7	83.6	1.1	15.3
SRC	long	2.4	79.5	1.3	19.7
	intermediate	2.6	83.9	1.0	15.1
	round	2.7	81.5	1.3	17.2
EGP	long	2.5	78.0	1.4	20.6
	intermediate	2.9	82.1	1.9	16.0
	round	2.9	80.0	2.8	17.2
MC	intermediate	3.0	82.1	1.2	16.7
	round	3.1	80.9	1.7	17.4
WC C75		2.6	82.0	1.8	16.2
MBH 110		2.7	71.6	2.5	25.9
Mean		2.7	80.7	1.7	17.7
SE ±		0.06	0.90	0.5	0.83

Dehulling was done using TADD

Values are mean of two determinations.

20 gram grain sample was used to dehull for 4 min by TADD.

Table 33 : Evaluation of dehulling quality of pearl millet grains of different shapes using a Barley pearler.

Cultivar/ grain shape		1000 grain wt(g)	Dehulling time Min	Sec	Recovery(%) Endos-sperm	Brokens	loss due to dehulling	1000 dehulled grain weight (g)
MELC	long	8.0	3	15	90.9	1.1	8.0	7.6
			4	0	87.4	1.8	10.8	7.6
			4	30	87.1	1.2	11.7	6.9
	intermediate	9.4	3	0	90.3	1.0	8.7	8.8
			3	30	88.2	1.4	10.4	9.2
			4	0	87.6	1.3	11.1	8.5
	round	10.6	2	50	89.3	1.3	9.4	9.2
			3	10	87.2	2.2	10.6	9.5
			3	30	86.2	2.2	11.6	9.8
SRC	long	8.0	3	15	89.8	1.1	9.1	7.7
			3	45	88.2	1.8	10.0	7.4
			4	30	86.3	2.0	11.7	7.6
	intermediate	10.2	3	0	89.8	1.2	9.0	8.9
			3	30	88.4	1.6	10.0	9.0
			4	0	86.5	1.9	11.6	8.9
	round	11.1	2	50	86.8	2.2	11.0	9.7
		-	3	00	84.9	2.9	12.2	9.9
			3	30	80.8	4.2	15.0	9.9
EGP	long	9.1	3	15	86.8	2.1	11.1	7.6
			3	45	84.0	3.2	12.8	7.7
			4	30	81.5	3.5	15.0	7.4
	intermediate	10.6	3	00	84.0	3.9	12.1	9.0
			3	30	81.6	5.0	13.4	9.2
			4	00	78.0	6.2	15.8	8.7
	round	12.1	2	30	83.6	4.4	12.0	11.0
			2	50	81.4	5.2	14.4	10.5
			3	00	80.5	5.5	14.0	10.4
MC	intermediate	11.1	3	0	84.6	3.6	11.8	9.3
			3	30	82.3	4.9	12.8	9.7
		-	4	0	76.9	6.3	16.8	9.2
	round	12.2	2	50	80.3	6.5	13.2	11.2
			3	10	79.6	6.4	14.0	10.5
			3	30	77.0	7.6	15.4	10.9
MC C75		10.2	3	0	86.0	2.4	11.6	8.7
			3	15	83.9	3.3	12.8	8.5
			3	45	82.3	3.9	13.8	8.9
MBH 110		10.4	3	0	81.0	6.8	12.2	9.0
			3	15	77.0	9.3	13.7	9.8
			3	45	73.8	10.0	16.2	8.5
Mean		10.2	-	-	84.2	3.65	12.25	9.0
SE ±		0.38			0.69	0.38	0.36	0.17

Values are based on single test of dehulling 100 g grains.

One thousand grains weight is the average of 5 determinations.