Grain Quality and Biochemistry
Progress Report 11/89

Pearl Millet

Report of Work

January 1986 - December 1987

ICRISAT

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

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FOREWORD

This report describes the various research activities carried out on biochemical, processing and food quality aspects of pearl millet from January 1986 to 1987. This work was carried out by Grain Quality and Biochemistry unit in collaboration with pearl millet breeding unit.

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

April 1990

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Breeding

Dr. Pheru Singh

Project No.: M-117(85) IC

Project Title: Breeding for protein content and quality.

Project Scientists: Pharu Singh
V. Subramanian

Objectives

a. Develop stable sources (lines) of high protein.

b. Utilize these sources in developing hybrids and varieties having high protein and grain yield.

c. Identify new sources of high protein with better agronomic traits.

d. Monitor the protein content and quality of elite products tested in advanced trials.

e. Study the inheritance of protein.

f. Evaluate the quality of protein and nutritional value of the high-protein lines.

Identification of new sources of high protein

Protein analysis of breeding nursery revealed a range of new lines with high protein content. About 3600 germplasm lines were screened for protein content and a few of them had protein content of more than 15%.

Protein content and quality of elite products

Significant differences in albumin and prolamin fractions were observed among the high protein genotypes. Albumin fraction of low-protein (9.9-11.3%) genotypes ranged from 20.6 to 23.5% whereas those of high-protein (14.4-19.9%) genotypes ranged from 15.8 and 19.5 %. The average decrease in albumin fraction in high-protein genotypes was 20%. This decrease was compensated by an increase of 15 % in prolamin fraction in high-protein genotypes. Globulin and glutelin fractions did not change much among these genotypes. However, it should be noted that the concentration of albumin fraction was considerably higher in high-protein lines when results were expressed on per gram basis due to 60 % increase in the protein content of these genotypes. This is very important from nutrition point of view.

Amino acid composition of high-protein genotypes (B 816, WC 190, and 700112) was compared with released cultivars (ICMS 7703 and WC C75). In general, pearl millet, like other cereals, is low in lysine, tryptophan, threonine, and sulphur-containing amino acids. Interestingly, the amino acid composition of these genotypes did not show large variation (Table 1). Lysine content of released cultivars was 3.27 and 3.38 g 100 g^{-1} protein whereas those of high-protein genotypes ranged between 2.66 and 2.94 g 100 g^{-1} protein. Thus a small decrease (about 15%) in lysine content of high-protein genotypes against about 60 % increase in their protein contents was observed. Noticeable difference in tryptophan content of these genotypes

Table 1. Amino acid composition [g (100 g)$^{-1}$ protein] of elite cultivars and high-protein pearl millet lines

Amino acid	ICMS 7703	WC C75	B 816	WC 190	700112	Mean	SE
Lysine	3.38	3.27	2.82	2.66	2.94	3.01	±0.136
Histidine	2.29	2.48	2.27	2.34	2.21	2.32	±0.045
Arginine	5.21	5.75	4.88	5.06	4.82	5.14	±0.166
Aspartic acid	8.92	8.89	8.78	9.02	9.02	8.93	±0.045
Threonine	3.95	4.00	3.85	3.79	4.01	3.92	±0.043
Serine	4.97	4.85	4.64	4.77	4.87	4.82	±0.055
Glutamic acid	20.84	20.25	20.15	21.56	20.52	20.66	±0.254
Proline	6.22	6.18	6.91	6.36	6.54	6.44	±0.133
Glycine	3.78	3.77	3.49	3.19	3.39	3.52	±0.113
Alanine	8.26	8.01	8.48	8.59	8.37	8.34	±0.099
Cystine	0.70	1.02	1.35	1.00	1.08	1.03	±0.103
Valine	5.68	5.57	5.83	5.72	5.85	5.73	±0.051
Methionine	1.66	2.19	2.03	1.41	1.81	1.82	±0.137
Isoleucine	4.76	4.58	4.85	4.82	4.87	4.78	±0.052
Leucine	10.50	10.44	10.72	11.06	10.81	10.71	±0.111
Tyrosine	3.57	3.47	3.41	3.32	3.32	3.41	±0.047
Phenylalanine	5.31	5.25	5.54	5.34	5.39	5.37	±0.049
Tryptophan	1.69	1.70	1.83	1.81	1.66	1.74	±0.034
Protein %	9.9	11.3	14.4	16.7	19.9	14.4	±1.81

was not observed. Pearl millet genotypes containing higher amount of prolamin fraction had slightly more proline amino acid but the differences were marginal when compared with the low-protein genotypes. No clear cut differences in the concentration of other essential amino acids were observed between low- and high-protein genotypes. Lysine and tryptophan contents of high-protein genotypes were markedly higher when the results were expressed as per gram sample as compared to that expressed on protein content basis, and this is of nutritional significance. This indicated that high protein content in pearl millet was not associated with reduced protein quality *per se*.

Cooperation with National Agricultural Research System

Grain protein and fat contents were determined in 42 cultivars supplied by Dr. Harainarayana, Project Coordinator, All-India Coordinated Pearl Millet Improvement Project.

This project was terminated in 1987

Project No. : **N-132(85) IC**

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

Project Scientist : **V. Subramanian**

Objectives

a) Standardize the methods of preparation 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 characteristics of pearl millet grain and food quality.

Food quality comprises of processing quality, culinary quality, and nutritional quality. Dehulling and milling quality are important processing methods for making various African foods.

Milling quality

The particle size of millet flour is important and influences texture of the foods. We studied the particle size distribution of flour and grits collected from food research laboratories in Niger and Senegal by V. Subramanian. Flour from dehulled grains used for making fura (thin porridge-like) contained the following distribution of particles: 26.7% retained on 45 mesh sieve; 54.7% passed through 100 mesh sieve (Table 2). Flour from dehulled grains for making bourou (thick porridge) had nearly a similar distribution. In case of flour used for couscous (steam-cooked product), which is granulated, it contained more than 35.9% of particles

Table 2. Particle size distribution of pearl millet flours and grits

	Percent retention on sieve (mesh)					
Flour/grits	20	45	60	80	100	>100
A. Flour used for *fura*[1]	0.15	26.7	8.1	7.0	1.9	54.7
B. Flour used for *bourou*[1]	0.15	23.9	11.2	9.3	2.3	50.4
C. Flour used for *cous cous*[1] (granulated)	15.1	35.9	8.2	7.0	2.4	29.7
D. *Brise*[2] (coarse grits)	99.2	-	-	-	-	-
E. *Sanxal*[2] (fine grits)	68.7	30.0	1.3	-	-	-
Mean	36.7	29.1	7.2	7.8	2.2	44.9
SE	±20.09	±2.58	±2.09	±0.77	±0.15	±7.72

[1]Sample collected in Niger

[2]Sample collected in Senegal

retained on 45 mesh sieve and 29.7% passed through 100 mesh sieve. The results suggest the existence of variation in flour particle size requirements for different foods. Coarse grits of pearl millet (brise) used for making tiakri (porridge-like), dugubu jen (rice-like) etc. collected from the Institut de Technologie Alimentaire, Senegal showed retention of about 99.0% of sample on 20 mesh sieve. Fine grits (sanxal) used for making lakh, cous cous etc. showed 68.7% and 30.0% retention on 20 and 40 mesh sieves respectively. Particle size index (PSI) was influenced by the grain characters as well as processing method. It will be useful in evaluating the PSI for testing the suitability of cultivars for various food uses in West Africa.

Food quality

A few traditional foods that are common in Niger and Mali were prepared with the help of scientists from these countries. Roti was also prepared. The food samples were processed and analyzed for chemical composition, amino acid composition and in vitro protein digestibility (IVPD). Changes in the chemical composition due to various processing methods are shown in Table 3. A reduction in protein content was observed in some of the foods except for uncooked -fura, and cous cous as compared to dehulled flour. Several amino acids in the foods showed an increase as compared to the grains, which may be due to the release of bound amino acids during cooking. Protein digestibility (IVPD) was reduced considerably in cous cous, neutral tô (Niger), and fura. However, in acidic tô(Mali) the digestibility showed considerable improvement. The IVPD of whole grain flour and roti was similar.

Table 3. Chemical composition and *in vitro* protein digestibility (IVPD) of pearl millet flour and foods preapred with BJ 104 grain, ICRISAT Center, 1986.

Flour/food	Percent							
	Protein	Fat	Ash	Starch	Sugars	Amylose	Fiber	IVPD
Dehulled flour	9.1	5.2	1.4	72.7	1.1	35.2	0.8	84
Fura (uncooked)[1]	10.3	6.5	1.8	67.3	1.9	31.2	1.4	85
Fura (uncooked)[1]	9.9	4.6	1.1	70.9	2.1	29.0	0.9	58
Fura (cooked)[1]	9.5	5.4	1.1	71.1	1.3	31.2	0.9	51
To (Niger)[1]	9.8	3.5	1.4	67.5	0.5	32.9	0.8	74
To (Mali)	9.5	3.7	1.5	67.1	1.0	32.9	0.8	92
Cous cous[1]	10.0	5.6	1.5	70.4	1.2	34.5	0.7	67
Roti[2]	10.7	5.4	-	70.3	1.9	-	1.3	84
Mean	9.9	5.0	1.4	69.7	1.4	32.4	1.0	74
SE	±0.18	±0.36	±0.09	±0.74	±0.19	±0.80	±0.09	±5.1

[1]Prepared from dehulled grain flour.

[2]Prepared from whole grain flour.

The *roti* quality of seven ICRISAT cultivars [ICMV 1 (WC C75), ICMV 4 (ICMS 7703) ICMS 7704, ICMH 451 ICMH 501, ICTP 8203 and white-seeded] was compared with 4 other cultivars. *Roti* quality was evaluated by a taste panel at Haryana Agricultural University (HAU), Hisar, as pearl millet *roti* is a common food in Haryana. Twelve persons scored *rotis* made under identical conditions, for color and appearance, texture, odor, taste, and general acceptability. *Rotis* from ICMV 1 (WC C75) and ICMH 451 were rated better than those from both control varieties for all traits evaluated (Table 4). *Rotis* from ICMV 4 (ICMS 7703) were generally comparable to those from the controls, except in texture. *Rotis* from ICTP 8203 were rated lower than the controls for most of the evaluated traits.

Relationship between physicochemical, structural, and processing characteristics and food quality

We confirmed that *roti* quality of flours was influenced by physical factors like swelling capacity of flour (r=0.82) and water-soluble flour fraction (WSFF, r=-0.87). The chemical factors, water-soluble protein and fat contents showed significant positive correlation with *roti* quality; amylose content was negatively correlated with *roti* quality.

We determined the chemical composition of grains of selected cultivars, which include ICRISAT elite cultivars, popular hybrids and local types. These were grown in Bhavanisagar in 1984. Grain protein content of ICMV 4 (ICMS 7703), ICTP 8203 and ICMH 451 was comparatively higher than ICMV 1, and Rajasthan local had the highest protein content (Table 5). ICMH 451 had higher fat content among the cultivars tested. Starch content of ICTP 8203, ICMS 7704 and ICMV 4 was lower as compared to other cultivars. Ash and crude fiber contents did not show variation among the

Table 4. *Roti* quality of pearl millet cultivars

Cultivar	*Roti* quality score[1]					
	Color and appearance	Texture	Flavor	Taste	Accepta-bility	Mean
ICMV 1	3.5	2.9	2.8	3.1	3.2	3.1
ICMV 4	2.9	2.4	2.7	2.9	2.7	2.7
ICMH 451	3.5	3.0	2.9	3.0	3.0	3.1
ICMH 501	3.1	2.9	2.6	2.5	2.4	2.7
ICMS 7704	2.9	2.4	3.1	3.0	2.9	2.8
ICTP 8203	2.4	3.1	2.4	2.4	2.4	2.5
White seeded	3.3	2.9	2.7	2.7	2.7	2.9
EX Bourno	3.3	3.0	2.8	2.8	2.9	3.0
BK 560	3.4	2.7	2.7	2.5	2.7	2.8
MBH 110	2.6	2.7	2.6	2.5	2.6	2.6
Rajasthan Local	2.9	2.8	2.8	2.9	2.9	2.8
Mean	3.1	2.8	2.7	2.8	2.8	2.8
SE	±0.11	±0.07	±0.05	±0.07	±0.07	±0.06

[1]Score : 1 = Poor; 4 = Excellent

Table 5. Chemical composition of pearl millet grains[1]

Cultivar	Percent					
	Protein	Starch	Fat	Ash	Sugars	Fiber
ICMV 1	10.0	71.8	6.9	2.0	2.0	1.4
ICMV 4	11.3	69.5	7.2	1.9	2.1	1.4
ICMH 451	12.6	70.7	7.6	1.9	2.2	1.4
ICMH 501	11.7	71.4	6.8	2.1	2.2	1.3
ICMS 7704	11.4	69.4	7.4	1.9	2.1	1.6
ICTP 8203	12.0	67.8	6.9	2.0	2.2	1.5
White seeded	11.6	74.3	6.4	2.2	2.2	1.7
EX Bourno	11.4	71.8	7.1	2.0	2.0	1.5
BK 560	11.7	70.2	6.8	2.1	2.2	1.3
MBH 110	12.3	71.6	6.4	2.1	2.2	1.3
Rajasthan local	13.4	70.6	7.1	2.0	2.1	1.6
Mean	11.8	70.8	7.0	2.0	2.1	1.5
SE	±0.26	±0.51	±0.11	±0.03	±0.02	±0.04

[1]Values are expressed on moisture free basis

cultivars. Our data indicated that four ICRISAT cultivars contained comparable quantities of chemical constituents as that of popular Indian hybrid MBH 110 and local (Rajasthan) cultivar.

The amino acid composition of the 11 cultivars is shown in Table 6. Protein quality in terms of amino acid composition including methionine + cystine, of all ICRISAT cultivars was better as compared to Rajasthan local variety except for threonine, phenylalanine and tyrosine. In addition to better protein quality, all cultivars also had more than 10% protein.

Prolamin content and its possible relation to dehulling quality

Dehulling was done using traditional method (TM), barley pearler (BP) and Tangential Abrasive Dehulling Device (TADD) with pearl millet grain of Pakiayabad (soft grain), SAD 448 (hard grain) and WC C75 (control) cultivars. The nitrogen distribution was determined in five solubility fractions, albumin-globulin (fraction I), prolamin (fraction II), cross-linked prolamin (fraction III), glutelin (fraction IV), and glutelin-like (fraction V), to study the variation in different proteins among the three cultivars obtained form whole and dehulled grain. Dehulled grain recovery of Pakiayabad was low while SAD 448 and WC C75 was higher by each of the three methods employed (Table 7). Albumin-globulin (fraction I) was higher in Pakiayabad as compared to the other two cultivars. Prolamin content (fraction II) was appreciably higher in SAD 448 (hard grain) and WC C75 as compared to Pakiayabad (soft grain) in the whole grain and in the dehulled grain. The reduction of prolamin in Pakiayabad was more pronounced in grains obtained by the traditional method than in mechanical dehulling method. The reduction was lower in SAD 448 and WC C75 as

Table 6. Amino acid composition (g (100 g)$^{-1}$ protein) of pearl millet grains

Amino acid	ICMV 1 (WC C75)	ICMV 4 (ICMS 7703)	ICMH 451	ICMH 501	ICMS 7704	ICTP 8203	White seeded	Ex Bourno	BK 560	MBH 110	Rajasthan local
Lysine	3.52	3.02	3.22	3.30	3.37	3.20	3.12	3.00	3.20	3.28	2.90
Histidine	2.57	2.48	2.58	2.41	2.49	2.47	2.52	2.39	2.35	2.26	2.51
Arginine	4.87	5.15	4.95	5.07	4.80	5.00	4.89	4.76	4.59	4.63	5.28
Aspartic Acid	8.92	8.19	8.68	8.53	8.31	8.46	8.86	9.00	8.44	9.10	8.74
Threonine	3.58	3.77	4.22	3.88	3.83	3.66	3.77	3.81	4.03	4.06	3.90
Serine	4.33	4.29	5.00	4.62	4.57	4.57	4.55	4.55	4.59	4.74	4.43
Glutamic Acid	18.61	18.86	18.78	18.69	18.30	18.55	18.06	18.59	18.69	18.39	18.18
Proline	5.67	5.98	6.55	6.23	5.91	5.80	5.64	5.72	6.29	5.56	5.62
Glycine	3.76	3.71	3.70	3.75	3.63	3.60	3.78	3.44	3.72	3.69	3.45
Alanine	7.36	7.06	7.96	7.62	7.35	7.20	7.29	7.30	7.21	8.34	7.41
Half Cystine	1.50	1.59	1.70	1.71	1.64	1.52	1.55	1.51	1.63	1.61	1.33
Valine	4.98	5.00	4.83	4.56	5.19	5.14	4.77	4.87	4.78	5.37	4.71
Methionine	2.30	2.43	2.53	2.46	2.35	2.11	2.24	2.46	2.31	2.31	2.01
Isoleucine	3.95	4.02	4.54	4.34	4.14	4.19	4.01	3.88	3.97	4.04	3.92
Leucine	9.41	9.20	9.16	9.14	9.47	9.20	8.92	8.93	8.50	8.66	8.65
Tyrosine	3.68	3.70	4.00	3.64	3.58	3.57	3.48	3.51	3.60	3.45	3.52
Phenylalanine	4.78	5.25	5.54	5.00	4.94	4.99	4.75	4.69	4.85	4.97	4.75
Mean	5.52	5.51	5.75	5.59	5.52	5.48	5.42	5.44	5.45	5.56	5.37
SE	±0.971	±0.970	±0.964	±0.963	±0.946	±0.962	±0.939	±0.971	±0.958	±0.962	±0.951
Protein (%)	10.0	11.3	12.6	11.1	11.4	12.0	11.6	11.4	11.7	12.3	13.4

Table 7. Distribution of protein fractions in whole and dehulled grain of pearl millet cultivars, ICRISAT Center 1986.

Cultivar/Details		Dehulled grain recovery (%)	Protein (%)	Protein fractions[1] [g (100 g)$^{-1}$ protein)]				
				I	II	III	IV	V
Pakistan (soft grain)								
Method of Dehulling	WG[2]	100.0	12.2	29.6	39.7	2.1	6.7	13.8
	TM[3]	68.8	12.0	14.2	29.6	1.8	2.8	11.7
	BP[4]	76.5	10.4	17.1	34.8	2.5	2.9	13.1
	TADD[5]	77.1	12.1	18.7	32.4	1.5	4.1	11.2
SAD 448 (hard grain)								
Method of Dehulling	WG[2]	100.0	13.6	23.1	46.6	1.8	5.5	11.4
	TM[3]	71.7	13.3	13.6	34.5	2.1	2.7	11.8
	BP[4]	89.5	12.8	17.0	44.4	3.0	2.9	13.1
	TADD[5]	88.3	12.7	18.8	44.6	1.4	5.3	11.1
WC C75 (control)								
Method of Dehulling	WG[2]	100.0	14.6	25.1	45.9	1.8	5.6	15.5
	TM[3]	75.3	14.0	13.4	36.6	1.7	3.1	12.7
	BP[4]	86.8	13.7	15.0	43.1	2.3	3.0	13.2
	TADD[5]	86.2	13.0	17.8	43.9	1.6	5.6	12.4
	Mean	85.0	12.9	18.6	39.7	3.2	4.2	12.6
	SE	±3.24	±0.32	±1.44	±1.69	±0.18	±0.42	±0.37

[1]Fraction I : albumin+globulin and free nitrogen; II : Prolamin;

III : cross-linked prolamin; IV : gluelin; V. glutelin-like

[2]WG : whole grain

[3]TM : dehulled by traditional method

[4]BP : dehulled by Barley pearler method

[5]TADD : deulled using Tangential Abrasive Dehulling Device

compared to Pakiayabad by the mechanical methods. Minor differences were observed for cross-linked prolamins (fraction III) among the cultivars. Glutelin (fraction IV) decreased due to dehulling in all the cultivars, and was more pronounced in traditional and barley pearler methods of dehulling. This study suggests that prolamin may play an important role in grain hardness and their ability to withstand the dehulling process. However, studies with more cultivars varying in their dehulling quality are required to confirm these observations.

This project was terminated in December 1987

Summary and Conclusions

A few lines that yield consistently high protein (>14%) have been identified. These lines can be used as a source for high protein, in developing hybrids, and composites, with improved grain yield. Further, high-yielding superior genotypes can also be converted to high-protein background.

Flour particle size distribution of pearl millet influenced the quality of African foods like <u>cous cous</u>, <u>fura</u>, and <u>hourou</u>. <u>In vitro</u> protein digestibility of acidic <u>tô</u> (Mali) was comparatively higher than neutral <u>tô</u> (Niger).

We confirmed that <u>roti</u> quality of flours was influenced by physical factors like flour swelling capacity and water-soluble flour fraction. <u>Roti</u> quality of ICMV 1, and ICMH 451 was rated higher than other cultivars. ICRISAT developed cultivars contained comparable quantities of chemical constituents as that of local cultivar. Grain hardness was related to prolamin content, which influenced recovery due to dehulling.

Publications

Mahalakshmi, V., Subramanian, V., Bidinger, F.R., and Jambunathan R. 1985. Effect of water deficit on yield and protein content in pearl millet grains. Journal of Science, Food and Agriculture, 36:1237-1242 (JA # 502).

Subramanian, V., Jambunathan, R., and Ramaiah, C.D. 1986. Physical and chemical characteristics of pearl millet grains and their relationship to roti quality. Journal of Food Science, 51(4):1005-1008 (JA # 498).

Singh, P., Singh, U., Eggum, B.O., Kumar, K.A., and Andrews, D.J. 1987. Nutritional quality evaluation of high protein genotypes of pearl millet (Pennisetum americanum (L.) Leeke). Journal of Science, Food and Agriculture, 38:41-48 (JA # 617).

Jambunathan, R., and Subramanian, V. 1987. Grain quality and utilizaton of sorghum and pearl millet. Pages 133-139 in Proceedings of the International Biotechnology Workshop, 12-15 January 1987, ICRISAT Center, India, Patancheru, Andhra Pradesh 502 324, India: International Crops Research Institute for the Semi-Arid Tropics (CP # 394).

Subramanian, V., and Jambunathan, R. 1987. Grain quality of sorghum, pearl millet, maize and minor millets. Proceedings of the Symposium on "Present Status and Future Perspectives in Technology of Food Grains", Central Food Technological Research Institute, 28 February - 1 March 1987, Mysore, India (CP # 352).

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