CP 0108

3 Chemical Composition and Food Quality of Sorghum*

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1. INTRODUCTION

Sorghum is the staple food grain for a large segment of the population in the semi-arid tropical regions. Though increasing the yield and its stability is of paramount importance, improving the grain quality also deserves attention. Sorghum grain quality is determined by several factors such as visual quality; nutritional quality, including digestibility and bioavailability of nutrients; antinutritional factors such as tannins; processing characteristics; cooking quality; and consumer acceptability. Hulse et al., (1980) have published an exhaustive review of the chemical composition and nutritive value of sorghum and millets. This report discusses the results of studies carried out at 1CRISAT on the nutritional quality of sorghum and gives a brief account of food quality, including consumer acceptance.

2. CHEMICAL COMPOSITION

Sorghum grains exhibit a wide range of variation in their chemical composition (Table 3.1).

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Table 3.1 Chemical Composition of Sorghum Grains

Constituent	No. of genotypes[a]	Range	Mean	SE±
Protein (%)	10479	4.4—21.1	11.4	0.10
Water soluble protein (%)	80	0.3-0.9	0.6	0.01
Lysine[b] (g/16g N)	412	1.06-3.64	2.09	0.09
Starch (%)	160	55.6—75.2	69.5	2.36
Amylose (%)	80	21.2—30.2	26.9	0.88
Soluble sugars (%)	160	0.7—4.2	1.2	0,03'.
Reducing sugars (%)	80	0.05—0.53	0.12	0.004
Crude fibre (%)	100	1.0—3.4	1.9	0.03
Fat (%)	160	2.1—7.6	3.3	0.06i
Ash (%)	160	1.3—3.3	1.9	0.01

[a] Includes germplasm accessions and breeding lines.
Values expressed on dry weight basis.
[b] Ion exchange chromatography.

2.1 Proteins

In many parts of Asia, the Near East, Africa and Latin America, nearly two-thirds of the dietary protein requirements come from cereals (Axtell, 1979). As sorghum is one of the staple cereals in these regions, a study of the quantity and quality of protein supplied by sorghum is important. We analysed a large number of sorghum genotypes and found that the grain protein varied from 4.4 to 21.1 per cent, with a mean value of 11.4 per cent (Table 3.1). Frey (1977) reported that a. negative correlation exists between yield and protein content in. several cereals, including sorghum.

The quality of grain protein depends on the levels of essential amino acids (FAO/WHO, 1973). The amino acid composition of M 35-1, IS 11758, SPV 386, and GG 1483 sorghum grains is given in Table 3.2. In general, sorghum has higher levels of glutamic acid, leucine, alanine, proline, and aspartic acid than of other amino acids. The essential amino acid:

Table 3.2. Amino Acid Composition of Sorghum Grains (g/16g Nitrogen)[a]

Amino acid	Cultivars			
	M 35-1	IS 11758	SPV 386	GG 1483
Lysine	2.60	3.29	2.26	2.54
Histidine	2.06	2.28	2.20	2.18
Arginine	4.20	4.86	3 89	4.12
Aspartic acid	7.21	8.12	7.36	7.21
Threonine	3.00	3.35	3.03	3.35
Serine	3.66	4.14	3.74	4.17
Glutamic acid	20.30	20.07	21.07	22.02
Proline	6,25	7.69	7.21	7.94
Glycine	3.45	4.20	3.34	3.42
Alanine	8.64	8.93	9.33	8.50
Cystine	0.97	0.81	1.11	0.94
Valine	4.39	5.46	4.69	4.75
Methionine	1.39	1.39	1.43	1.46
Isoleucine	3.83	4.30	4.03	3.83
Leucine	12.27	12.11	12.30	13.07
Tyrosine	3.25	3.38	3.34	3.51
Phenylalanine	4.55	4.91	4.59	4.63
Total	92.02	99.29	94.92	97.64

[a] Ion exchange chromatography.

composition showed a wide variation among sorghum cultivars. A comparison of amino acid scores calculated on the basis of the FAO/WHO (1973) pattern for the essential amino acids of a few promising cultivars is given in Table 3.3. The essential amino acids in the high lysine Ethiopian line (IS 11758) were comparatively high. However, the grains of this line are shrivelled. The lysine score of SPV 351, SPV 396, GG 1483, CSH 8, and M 35-1 ranged from 45 to 48. As in other cereals, lysine is the first limiting amino acid recorded in sorghum (Adrain and Sayerse, 1957).

Table 3.3. Essential Amino Acid Chemical Score for Nine Sorghum Cultivars[a]

Amino acid	FAO/WHO pattern (g/16g N)	M 35-1	CSH 8	IS 11758	SPV 351	SPV 387	GG 1483	M 36357	SPV 393	SPV 396	Mean score
Lysine	5.5	47	48	60	45	38	46	42	38	48	46
Threonine	4.0	75	80	84	74	76	84	77	78	87	79
Methionine + Cystine	3.5	67	70	63	76	74	69	66	72	70	70
Leucine	7.0	175	180	173	170	182	187	186	180	179	179
Isoleucine	4.0	96	95	108	90	100	96	100	95	93	97
Valine	5.0	88	107	109	88	92	95	96	89	93	95
Phenylalanine + Tyrosine	6.0	130	140	138	126	132	136	143	135	137	135

[a]Comparison was made by keeping 100 as the unit for FAO/WHO pattern of each of the amino acids.

Studies on increasing lysine content in sorghum indicated that derivatives of crosses of P 721 produced only a marginal increase in lysine content in grain, and these selections had low kernel weight and floury endosperm similar to their P 721 parent (Riley, 1980). In contrast, Jaya Mohan Rao (1980) observed that the crosses N 93xP 721, N 49XP 721, and N 55 X P 721 were the best combinations for increasing the protein and lysine contents with a plump-seed background. Plump-seeded segregants with high protein (up to 16 per cent) and high lysine (2.7-3.9 per cent) have been isolated (Jaya Mohan Rao, 1980).

The protein quality of sorghum is also associated with the different proportions of various protein fractions in the grain. Fractionation studies indicated that the distribution of albumin-globulin, prolamin, and glutelin in sorghum is about 15, 26, and 44 per cent, respectively, of total nitrogen in sorghum grains. (Table 3.4). In high-lysine sorghums (TS 11167 and IS 1175S),

Table 3.4. Nitrogen Distribution in Whole Kernels of Sorghum[a]

	Cultivars			
Fraction	M 35-1	P 721	SPV 351	CS 3541
I (albumins and globulins)	14.2	12.2	18.0	17.2
II (kafirin)	15.4	7.4	12.9	16.2
III (cross-linked kafirin)	18.2	8.3	12.0	14.7
IV (glutelin-like)	3.6	2.8	4.7	3.7
V (glutelin)	38.9	43.6	41.8	36.2
VI (residue)	4.5	10.6	7.5	8.8
Total	94.8	85.1	96.9	96.7

[a] Per cent of total nitrogen

the proportion of prolamin is lower and the albumin-globulin fraction is higher than normal sorghums such as redlan, thus improving the overall protein quality (Jambunathan et al., 1975).

2.2 Carbohydrates

The total soluble sugars of sorghum ranged from 0.7 to 4.2 per cent and the reducing sugars, from 0.05 to 0.53 per cent (Table 3.1). Studies on fractionation of sugars using Biogel P.2 column indicated the presence of stachyose, raffinose, sucrose, and glucose + fructose (Subramanian, et al., 1980); of these, sucrose was the predominant sugar. The flatulence-causing oligosaccharides, stachyose and raffinose, were also present in varying proportions.

Starch is the major constituent of sorghum, accounting for *56* to 75 per cent of the total dry matter in the grain (Table 3.1). Our studies with 100 germplasm accessions indicated that starch content was negatively and significantly correlated with protein content (unpublished data). The physicochemical characteristics of starch are influenced by the amylose content in sorghum (Miller and Burns, 1970). Waxy sorghums have a low amylose content (Deatherage et al., 1955), In non-waxy sorghums, the amylose content varied from 21.1 to 30.2 per cent, while water-soluble amylose varied from 3.1 to" 12.7 per cent (Table 3.1). The gelatinisatibn temperature of starch is affected by the proportion of amylose to amylopectin in starch (Hoseney et al., 1981). The variation in the gelatinisation temperature of starch for 12 genotypes was from 66.0 to 70.5°C (Subramanian et al., 1982). The swelling capacity and solubility of starch at different temperatures also showed wide variation for the genotypes studied (Subramanian et al., 1982).

2.3 Fat, Crude Fibre and Minerals

The fat content in sorghum ranged from 2.1 to 7.6 per cent, crude fibre from 1.0 to 3.4 per cent, and ash from 1.3 to 3.3 per cent (Table 3.1). Phosphorus, potassium, and magnesium were found in appreciable amounts in the sorghum grain (Table 3.5). The wide range in mineral and trace element composition indicated that sorghum is a good source of minerals. The mineral composition is, however, influenced by the environmental conditions (Deosthale and Belavady, 1978).

Table 3.5. Mineral and Trace Element Composition (mg/l00g) of 99 Selected Sorghum Germplasm Accessions

Element	Range	Mean	SE±
Phosphorus	388—756	526	4.8
Magnesium	167—325	212	3.0
Potassium	363—901	537	10.3
Iron	4.70—14.05	8.48	0.24
Copper	0.39— 1.58	0.86	0.05
Zinc	2.49— 6.78	3.91	0.14
Manganese	0.68- 3.00	1.75	0.07

2.4 Polyphenols

Sorghum contains polyphenols, which are generally associated with grain pigmentation (Hoseney et al., 1981). Polyphenols, commonly referred to as tannins, interfere with the bioavailability of nutrients (Jambunathan and Mertz, 1973). It has been reported that sorghum grains contain substantial quantities of condensed tannins and trace amounts of hydrolysable tannins (Strumeyer and Malin, 1975). Brown sorghums with high tannin are known to be resistant to bird depredation (Tipton et al., 1970) and have reduced preharvest germination (Harris and Burns, 1970) and grain moulding (Harris and Burns, 1973). Analysis of 10 sorghum genotypes with brown seeds indicated that tannin estimated as catechin equivalents varied from 0.13 to 7.22 per cent (Table 3.6). The tannin content of IS 10301, 8748, 3171, and 3031 varied considerably, though the grains of these genotypes had nearly similar colour (Table 3.6). The breaking strength as measured by the Kiya grain hardness tester showed considerable variation among the genotypes. It may be possible to remove tannin from sorghum grains by dehulling them. However, they can be dehulled only if the grains are hard enough (vitreous endosperm) to withstand the dehulling process, and the grains of brown sorghums are generally soft and less corneous. The breaking strength of IS 3031 grains was higher than that of other genotypes, and such hard-grain

Table 3.6. Grain Characteristics and Tannin Content of Brown Sorghums

IS No.	Colour of grain	Munsell colour coding[a]	Corneousness[b]	100-grain wt (g)	Breaking strength[c] (KG)	Tannin (CE)[d] %
724	Dark brown	2.5 YR 2.5/6	4	1.33	3.3	3.68
1109	Reddish brown	10 R 3.5/6	4	1.91	4.1	0.62
2880	Dark brown	2.5 YR 2.5/6	5	1.48	2.0	5.72
3031	Dark brown	2.5 YR 2.5/6	4	1.76	6.3	7.22
3149	Brick red with yellow	2.5 YR 4.5/5	3	2.29	5.4	0.24
3150	Dull brown	5 YR 3.5/6	3	1.67	2.4	1.34
3171	Dark brown	2.5 YR 2.5/6	5	2.26	3.0	2.14
8748	Dark brown	2.5 YR 2.5/6	5	2.42	2.7	0.86
8754	Dull brown	2.5 YR 3/6	3	1.29	3.7	2.18
10301	Dark brown	2.5 YR 2.5/6	4	2.74	4.2	0.49

[a]Colour coding was given by comparing grain colour with Munsell colour chart.

[b]Corneousness of endosperm was visually scored for the proportion of corneous/floury endosperm; 3: partly corneous, 4: almost floury and 5: completely floury.

[c]Breaking strength was determined as the force in kg required to break the grain, using Kiya grain hardness tester. (S.E. $\pm$0.71).

[d]C.E.: Catechin equivalents (S.E. $\pm$0.063).

types can perhaps be dehulled more effectively. Our study indicated that there are certain dark brown sorghums with low tannin, which may be useful in developing bird resistant lines.

3. FOOD QUALITY AND CONSUMER ACCEPTANCE

3.1 Sorghum Food Products

A detailed survey on the traditional methods of food preparations of sorghum grains was undertaken in seven states of India (Subramanian and Jambunathan, 1980). For making acceptable foods, sorghum grains are processed by dry milling, wet milling, fermentation, roasting, and puffing. Based on our survey, the different kinds of foods made from sorghum in India were classified as *roti,* porridge, gruel, and cooked, steamed, and fried sorghum, and other types. Generally, sorghum is consumed in the form of *roti* or *bhakri* in India. Studies have been undertaken at ICRISAT to find out the suitability of sorghum grains for making various traditional foods. These included evaporation of food types like *roti,* porridge, boiled sorghum, etc. Standard methods of *roti* preparation, including the evaluation of dough quality and *roti* characteristics, have been described earlier (Murty and Subramanian, 1982; Murty et al., 1982).

3.2 Dough Quality

A flour that can give a good, cohesive dough generally produces an acceptable *roti.* Dough cohesiveness was evaluated with the Instron food testing instrument using a back extrusion cell. Cohesive doughs yielded a characteristic back extrusion profile requiring less force for deformation. Poor quality dough that is less cohesive gets compressed into the cell without extrusion (Fig. 3.1). Studies were made on the influence of water soluble extracts of flour on dough stickiness. The flour of IS 12611 and M 35-1 gave good cohesive dough, and that of Simila and P 721 gave dough with less cohesiveness. Each flour sample was extracted with distilled water; the resulting slurry was centrifuged, and the supernatant was termed "water soluble". The water solubles obtained from IS 12611 flour were added to Simila flour in place of water, and a dough was made. Measure-

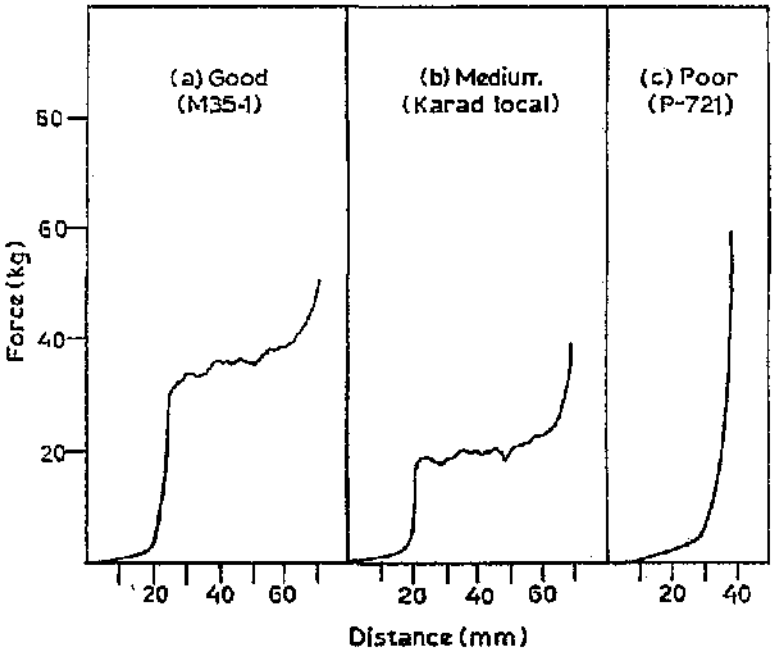

Fig. 3.1. Force-distance Curves for Good, Medium and Poor Quality Doughs of Sorghum Flour (Instron).

ment by the Instron machine showed that the dough thus prepared was considerably better than the dough made by adding water to Simila flour. Similar studies were made using the combination of M 35-1 and P 721 flours. Here again the cohesiveness of P 721 flour was improved considerably when the "water solubles" of M 35-1 were added in place of water. This indicated that water soluble components play an important role in the quality of dough. The protein content in the water soluble fraction ranged from 0.3 to 0.9 per cent of meal. Gel filtration of the water soluble protein using Sephadex G 100 (phosphate buffer, pH 7.6) yielded two major peaks. There is a need to investigate the nature and role of the water soluble components, including their pentosan content and thiol and disulphide components in flour and their influence on dough and *roti* quality.

3.3 *Roti* Quality

Rotis were made under identical conditions and their quality was evaluated by a trained taste panel for colour, appearance, texture, flavour, taste, and keeping quality. *Roti* of a pale yellow colour was generally acceptable. Panelists' scores for taste, texture, flavour, and keeping quality varied significantly for 167 genotypes with visually good grains (Murty et al., 1982). White grains with coloured spotting or a testa and brown types produced a dark red or dark brown *roti.* In general, pale yellow grains with intermediate corneous endosperm, and with a thin pericarp without testa produced *roti* with acceptable quality. Waxy and floury grains produced poor quality *rotis.*

3.4 Relationship between *roti* Quality and Physiochemical Properties of the Grain

The physical characteristics of grain, like 100-grain weight, hardness, swelling capacity, and flour swelling capacity in water, and water soluble flour fraction were determined, using grain samples from 45 cultivars (Subramanian and Jambunathan, 1982). Protein, water soluble protein, starch, amylose, and water soluble amylose contents in flour were also determined. *Rotis* made under identical conditions were evaluated by a taste panel for colour, flavour, taste and texture. The relationship between the physiochemical characters and *roti* quality indicated that quantity of water soluble protein, amylose and sugars jointly influence the *roti* quality (Subramanian and Jambunathan, 1982). In order to find a quick screening method to predict flour quality for making suitable foods, the quick tests that were followed for rice and wheat such as the alkali spreading test, gel consistency test, and 2-chloro-ethanol test are being carried out. The relationship of food quality with the results of the foregoing tests will be determined.

The cultivars M 35-1 and Simila have similar chemical composition of grains and *rotis.* The grains of M 35-1 are pale yellow and those of Simila are light brown and contain tannin. The nutrient composition of sorghum grain and *roti* from these two cultivars is given in Table 3.7. However, M 35-1 grains produced an acceptable *roti* while Simila produced a poor *roti* with

Table 3.7. Nutrient Composition and Digestibility of Sorghum Flour and *Roti* (per 100 g)

Component	Flour[a]		*Roti*	
	M 35-1	Simila	M 35-1	Simila
Protein (g)	9.3	10.9	9.5	10.S
Fat (g)	3.4	3.3	2.9	2.8
Starch (g)	73.2	69.0	72.7	69.5
Soluble sugars (g)	1.1	1.1	1.1	1.0
Ash (g)	1.4	1.5	1.3	1.6
Crude fiber (g)	1.5	1.8	1.4	1.8
Thiamine (mg)			0.22	0.06
Niacin (mg)			4.4	4.3
Calories[b]	365	354	359	350
Starch digestibility (α-amylase)[c]			48.2	38.4

[a] Flour was obtained by grinding whole grains.
All values are on dry weight basis.
[b] Calculated value.
[c] mg maltose released from 100 mg *roti* in 4 hours (values corrected for moisture content in *roti).*

unacceptable texture. *Roti* prepared from M 35-1 grains had a higher *in vitro* starch digestibility than that prepared from Simila.

3.5 Consumer Acceptance of Local and Hybrid Sorghum

During our survey on the food consumption pattern of sorghum in Maharashtra state, the farmers and other consumers informed us that they preferred local sorghums to hybrid sorghums. They were of the opinion that *bhakri (roti)* made of local sorghum *(maldandi)* kept them without hunger for a longer time than that prepared from hybrids. To test whether this effect was real or psychological, a preliminary study was conducted in Rahuri area (Maharashtra) with the help of six families. Sorghum flour of a hybrid (CSH 8) and a local (M 35-1) were supplied to each of the family members for a period of four weeks and their consumption pattern was assessed. Analysis of results revealed that four of six families could not differentiate between the hybrid and local sorghum (Table 3.8). However,

Table 3.8. Consumer Preference of Hybrid and Local Sorghums

Type	Daily trial[a]								Weekly trial[a]			
	Family A		Family B		Family C		Family D		Family E		Family F	
	A	NA	A	NA	A	NA	A	NA	A	NA	A	NA
Hybrid (CSH 8)	4	11	11	1	16	1	7	4	16	0	7	0
Local (M 35-1)	13	1	15	3	10	1	16	0	14	0	23	0
X^2	13.07		0.088		0.099		3.87		—		—	
P	<0.01		NS		NS		<0.05		NS		NS	

[a]Indicates the number of days of response for acceptability or non-acceptability

A : Acceptable NA : Not acceptable

P : Level of significance NS : Not significant it is necessary to carry out consumer acceptability studies on advanced breeding materials before they are considered for large-scale testing and subsequent release.

4. CONCLUSIONS

Sorghum contains adequate quantities of nutrients such as protein, carbohydrate, fat and minerals to meet the daily requirements of humans. The protein quality of some genotypes appears to be comparatively better with respect to their amino acid composition. Lysine is the most limiting amino acid in sorghum. Starch accounts for about 56 to 75 per cent of the total dry matter in sorghum. The physical characteristics of starch such as gelatinisation temperature, swelling power, and solubility are variable. The sorghum grain contains 1.3 to 3.3 per cent ash, and minerals like phosphorus, potassium and magnesium in varying quantities. The tannin content (catechin equivalents) of brown sorghum grain ranged from 0.13 to 7.22 per cent.

The *roti-making* quality of sorghum grains varied considerably. A cohesive dough yielded a characteristic back extrusion profile, while a less cohesive dough was compressed and showed no extrusion. The quantity of water-soluble protein, amylose, and sugars in flour jointly influence the *roti* quality. Preliminary experiments conducted on the acceptance of sorghum *bhakri* revealed that consumers could not distinguish between M 35-1 and CSH 8 sorghum.

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