THE CHEMICAL AND ESSENTIAL AMINO ACID COMPOSITION OF TWENTY-FIVE SELECTIONS OF GRAIN SORGHUM[1]

RICARDO BRESSANI[2] AND BERTA J. RIOS[3]

ABSTRACT

The paper reports on the chemical and essential amino acid composition of twenty-three imported and two native samples of grain sorghum grown in Guatemala in 1958. At a single location, ten varieties and thirteen hybrids of imported seed and one native sample were grown. For comparative purposes, one native sample was grown in a different locality. Average values for varieties and hybrids respectively were: protein, 9.4 and 8.9%; ether extract, 3.7 and 3.4%; crude fiber, 2.5 and 2.6%; ash, 2.64 and 2.61%; calcium, 18.51 and 18.23 mg.%; phosphorus, 481 and 519 mg.%; thiamine, 0.30 and 0.22 mg.%; riboflavin, 0.23 and 0.15 mg.%; and niacin, 2.78 and 2.96 mg.%, expressed on 14% moisture basis. The two native samples were higher in average content of protein, thiamine, and niacin, and lower in average content of ash, calcium, phosphorus, and riboflavin.

Significant differences in essential amino acid composition were found among the 25 samples, reflecting the genetic variability in the imported material studied. Nevertheless, the similarity in chemical composition of grain sorghum to maize indicates that grain sorghum can replace maize without significantly changing the nutritive value of the diet or ration.

The competition between human and animal consumption of maize is one contributing factor to the serious nutrition problem in the rural areas of Central America (4,5,9). Until recently, maize was grown primarily for human feeding, but the new upsurge in animal production, particularly of poultry, has made it necessary to find substitutes for maize that would reduce the competition for this cereal. For several reasons, one of the most acceptable cereal grains is sorghum, which is used in the preparation of tortillas for human consumption whenever there is a shortage of maize, and which, when properly cultivated, is a higher-yielding crop than maize in regions with low soil fertility and dry climate (18,21).

Studies carried out by Hubbard *et al.* (16), Adrian and Sayerse (1), and others (19,20) have shown that grain sorghum is similar to maize in its chemical and anatomical composition. Tanner *et al.* (23) studied the B-complex vitamin content in 42 samples of grain sorghum, reporting a content of riboflavin and pyridoxine similar to that found in maize and a higher content of niacin, pantothenic acid, and biotin. The authors also found the niacin content to be highly variable.

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[2] Chief, Division of Agricultural and Food Chemistry, Institute of Nutrition of Central America and Panama (INCAP), Guatemala, C.A.

[3] ICA fellow in INCAP.

The amino acid composition of grain sorghum was reported by Adrian and Sayerse (1) and by Close and Naves (11). The findings of these workers and those of Pond *et al.* (18) and Shelton *et al.* (21) demonstrated that grain sorghum varieties had the same relative lysine deficiency as other cereals. Adrian and Sayerse (1) also mentioned the presence of nearly as large quantities of leucine in the protein of sorghum as in that of maize (8).

The present study was carried out for the purpose of obtaining additional knowledge on the variation in nutritive value of grain sorghums which might facilitate selection of varieties with an improved content of essential nutrients.

Materials and Methods

Twenty-three selections of grain sorghum, grown from seeds imported from Texas, were analyzed; of these 10 were varieties and 13 were hybrids. The material was obtained through the courtesy of SCIDA[4] which planted the seed of the varieties and hybrids in the locality of Salama, Baja Verapaz, in 1958 as part of their basic crop introduction program. Two 1958 samples of native sorghum were also studied; 346908-V Criolla was grown in the same Salama locality and Saucite Criolla, in Barcenas, near Guatemala City. A sample of 250 g. was brought to the laboratory and ground to pass 40-mesh, then stored at 4°C. until analyzed.

Moisture, obtained by using a vacuum oven, and nitrogen, ether extract, ash, crude fiber, and calcium were determined according to the AOAC *Methods of Analysis* (3). Phosphorus determinations followed the method of Fiske and Subbarow (13), with the modification of Lowry and Lopez (17). Thiamine was estimated by the Hennessey and Cerecedo procedure (14) and riboflavin by the Hodson and Norris (15) method after hydrolysis with 0.1*N* sulfuric acid by steaming in the autoclave at atmospheric pressure for 30 minutes, followed by enzymatic hydrolysis with Takadiastase. The niacin content was determined microbiologically with *Lactobacillus arabinosus* 17-5 and Difco media[5] after hydrolysis of the samples with 1*N* sulfuric acid in the autoclave at 15 lb. pressure for 30 minutes. For microbiological determinations of amino acid content, a hydrolysate was prepared by refluxing 1-g. samples with 6*N* hydrochloric acid for 24 hours, filtering, and adjusting to pH 6.8 and to volume. All tubes received 2 cc. of media and were filled to 4 cc. with distilled water. Five concentrations of each hydrolysate were replicated three times. After inoculation, the tubes

[4] Mr. A. A. Arriaga, in Charge of Agricultural Programs of Rice and Sorghum. Department of Basic Crops, Servicio Cooperativo Interamericano de Agricultura, Guatemala City, Guatemala.

[5] Difco Laboratories, Detroit, Michigan.

were incubated for 72 hours at 38°C. and titrated with 0.01*N* sodium hydroxide using bromthymol blue as the indicator.

Difco medium was used for the assay of lysine, methionine, leucine, isoleucine, arginine, phenylalanine, and tyrosine, with *Leuconostoc mesenteroides* P-60 as the test organism. This strain of bacteria was also used for the assay of histidine and valine with the media recommended by Steele *et al.* (22). The threonine content was estimated using *Streptococcus faecalis* and the media of Steele *et al.* (22). Tryptophan assays were carried out on alkaline hydrolysates with Difco medium and *Lactobacillus arabinosus* 17-5.

Results

The moisture, protein, ether extract, crude fiber, ash, calcium, and phosphorus contents of the 25 grain sorghum selections are shown in Table I. Moisture was rather constant, while the protein concentration ranged from a low value of 7.6 to a high one of 12.5 g.%. Only a very small average difference was found between the hybrids and the variety sorghum samples. The two native samples were higher in protein than all but one of these.

The ether extract presented no large differences among hybrids, varieties, or the native grain sorghums; the 25 samples ranged from 3.1 to 4.5 g.%. The native, hybrid, and variety samples of grain sorghum did not differ on the average in crude fiber content. The ash content ranged from 1.39 to 3.84 g.% in the 25 samples. The average ash content of the thirteen hybrids and of the ten varieties was slightly higher than that of the two native grains. The calcium and phosphorus content of the two native samples was lower than the averages found for the hybrids and the varieties.

The thiamine, riboflavin, and nicotinic acid content of the 25 samples of grain sorghum is shown in Table II. The average thiamine content of the two native sorghum samples was twice as high as that found for the hybrid and variety samples. The riboflavin content, however, was lowest in the two native sorghum samples. The nicotinic acid content of the thirteen hybrid samples and the ten variety samples was similar, and that of the two native samples was slightly higher.

The amino acid composition of the 25 selections of grain sorghum expressed as mg. of amino acid per g. of nitrogen is given in Table III. The average values for arginine, histidine, isoleucine, tyrosine, threonine, and valine were similar among hybrids, varieties, and the native grain sorghum samples. The leucine, lysine, phenylalanine, and tryptophan content of the hybrids and varieties was similar and

TABLE I

CONTENT OF PROTEIN, ETHER EXTRACT, CRUDE FIBER, ASH, CALCIUM, AND PHOSPHORUS OF 25 SELECTIONS OF SORGHUM GRAIN[a]

SAMPLE	PROTEIN[b]	ETHER EXTRACT	CRUDE FIBER	ASH	CALCIUM	PHOSPHORUS
	%	%	%	%	mg %	mg %
Texas 601-H	10.2	3.8	2.4	1.58	13.03	295
Texas 611-H	8.1	3.4	2.9	3.02	20.44	562
Texas 620-H	8.5	4.4	2.7	3.42	16.45	595
Texas 660-H	8.5	3.6	2.1	3.38	47.22	589
RS-590-H	8.2	4.1	2.7	2.07	11.73	396
RS-610-H	7.6	3.7	2.6	2.97	19.23	542
RS-650-H	8.7	3.5	2.6	2.10	11.22	377
S-210-H	12.5	3.2	2.8	1.90	10.97	393
H11×71-H	10.4	3.2	2.0	1.39	22.31	238
H11×51-H	11.1	4.5	2.8	3.08	17.47	563
H11×41-H	10.6	3.2	2.0	2.98	12.15	584
H11×65-H	8.8	3.5	2.5	3.07	17.63	560
H11×61-H	8.5	3.3	2.9	3.37	20.91	548
Average for imported hybrids	9.4	3.7	2.5	2.64	18.51	481
Combine Kafir-60-V	8.1	3.5	2.9	2.77	13.48	536
Plainsman-V	8.9	3.6	2.8	3.84	18.20	603
Midland-V	8.4	3.2	2.3	1.78	10.99	354
Caprock-V	10.0	3.4	3.0	3.07	21.19	512
Redbine-60-V	10.2	3.2	2.1	2.48	11.94	414
Westland-V	9.0	3.3	2.6	3.73	45.53	1097
Norghum-V	9.0	3.9	2.8	2.43	17.18	479
Martin-V	8.5	3.1	2.1	2.09	14.59	373
Combine 7078-V	9.1	3.1	2.6	1.63	12.06	413
Hegary-V	8.2	3.5	2.5	2.33	17.12	416
Average for imported varieties	8.9	3.4	2.6	2.61	18.23	519
346908-V Criolla	10.9	3.0	2.1	2.54	16.43	489
Saucite Criolla	12.4	3.6	2.6	1.46	11.33	243
Average for native varieties	11.6	3.3	2.3	1.99	13.86	366
Average all samples	9.4	3.4	2.6	2.57	18.01	487

[a] All values expressed on 14% moisture basis.
[b] Protein = %N × 6.25.

slightly higher than the average content of these amino acids in the native grain. The variety and native grain sorghum samples were similar in their average content of methionine, and slightly higher than the average mg. of methionine per g. of nitrogen of the thirteen hybrid grain sorghum samples.

When expressed on a percentage basis, the two native grain sorghum samples showed generally higher averages in all of the amino acids except tryptophan, inasmuch as they also had a higher percentage of nitrogen. Both the thirteen hybrid samples and the ten variety samples showed similar average concentrations of all the amino acids

TABLE II

THIAMINE, RIBOFLAVIN, AND NICOTINIC ACID CONTENT OF 25 SELECTIONS OF SORGHUM GRAIN[a]

SAMPLE	THIAMINE	RIBOFLAVIN	NICOTINIC ACID
	mg %	*mg %*	*mg %*
Texas 601-H	0.38	0.22	3.02
Texas 611-H	0.20	0.24	3.07
Texas 620-H	0.24	0.20	2.75
Texas 660-H	0.20	0.17	2.71
RS-590-H	0.26	0.22	2.47
RS-610-H	0.29	0.22	2.79
RS-650-H	0.28	0.20	2.98
S-210-H	0.46	0.19	2.20
H11×71-H	0.33	0.27	2.71
H11×51-H	0.29	0.29	2.56
H11×41-H	0.32	0.26	3.28
H11×65-H	0.34	0.21	2.77
H11×61-H	0.30	0.28	2.88
Average for imported hybrids	0.30	0.23	2.78
Combine Kafir-60-V	0.20	0.11	2.81
Plainsman-V	0.11	0.15	2.39
Midland-V	0.30	0.16	3.44
Caprock-V	0.14	0.17	2.05
Redbine-60-V	0.14	0.10	1.84
Westland-V	0.09	0.11	3.06
Norghum-V	0.31	0.18	4.19
Martin-V	0.36	0.12	2.06
Combine 7078-V	0.25	0.29	3.03
Hegary-V	0.28	0.12	4.81
Average for imported varieties	0.22	0.15	2.96
346908-V Criolla	0.44	0.08	3.05
Saucite Criolla	0.53	0.10	3.73
Average for native varieties	0.48	0.09	3.39
Average all samples	0.28	0.19	2.90

[a] All values expressed on 14% moisture basis.

on a percentage basis. The variation among the 25 selections was rather wide.

Discussion

A general comparison of the chemical composition of maize and sorghum shows a similarity in their protein content, although maize has a slightly higher content of ether-extractable substances and grain sorghum has a content of ash and crude fiber which is nearly twice that of maize. Both the calcium and phosphorus contents of grain sorghum grown in Central America are also higher than the amounts generally found in maize (2,6). In vitamin content, sorghum grain averages lower in thiamine than maize (2), although the data pre-

TABLE III

ESSENTIAL AMINO ACID COMPOSITION OF 25 SELECTIONS OF SORGHUM GRAIN

VARIETY	ARGININE	HISTIDINE	ISO-LEUCINE	LEUCINE	LYSINE	METHI-ONINE	PHENYL-ALANINE	TYROSINE	THREONINE	TRYP-TOPHAN	VALINE	NITROGEN
	mg/gN	*mg/gN*	*mg/gN*	*mg/gN*	*mg/gN*	*mg/gN*	*mg/gN*	*mg/gN*	*mg/gN*	*mg/gN*	*mg/gN*	%
Texas 601-H	291	148	263	888	180	83	201	145	205	32	353	1.64
Texas 611-H	351	194	279	811	194	103	229	150	282	45	318	1.32
Texas 620-H	268	195	310	971	178	106	275	160	278	46	412	1.38
Texas 660-H	330	212	294	937	180	95	249	163	272	54	378	1.38
RS-590-H	281	225	294	854	229	106	321	187	244	41	393	1.34
RS-610-H	298	244	322	927	215	102	345	151	265	58	389	1.23
RS-650-H	297	217	295	903	186	85	275	167	238	45	351	1.42
S-210-H	263	191	261	815	156	82	244	159	223	33	342	2.00
H11×71-H	287	200	267	793	155	80	293	151	200	39	345	1.68
H11×51-H	302	208	306	900	177	86	293	166	227	43	380	1.79
H11×41-H	248	190	294	864	145	83	283	151	248	45	321	1.71
H11×65-H	317	219	303	923	183	92	290	157	230	48	400	1.43
H11×61-H	319	245	345	926	207	108	286	187	237	56	420	1.37
Combine Kafir 60-V	373	239	291	888	196	106	299	184	230	55	404	1.32
Plainsman-V	340	223	288	893	192	98	309	191	236	50	346	1.43
Midland-V	352	214	332	989	201	100	334	204	267	56	436	1.36
Caprock-V	242	168	284	914	176	98	232	143	210	32	349	1.62
Redbine 60-V	208	157	260	805	165	93	235	137	205	35	318	1.65
Westland-V	263	209	295	950	193	127	263	190	224	37	410	1.47
Norghum-V	290	216	310	924	218	121	271	195	230	43	381	1.46
Martin-V	310	194	294	861	185	116	236	161	246	33	394	1.38
Combine 7078-V	273	215	298	913	177	111	265	210	263	49	398	1.48
Hegary-V	300	217	318	968	188	118	256	201	278	44	372	1.33
346908-V-Criolla	301	198	308	923	175	125	251	185	248	39	404	1.80
Saucite Criolla	265	196	272	903	155	112	224	175	228	34	355	2.07
Average	295	205	295	894	184	101	270	171	240	44	375	1.52
FAO reference protein pattern	...	..	270	300	270	270	180	180	180	90	270	...
Corn[a]	320	170	360	1050	260	170	320	340	260	43	390	1.39

[a] See reference 10.

sented showed that some of the samples contained high amounts of this vitamin. The variation observed is rather large and in the imported seeds, at least, may be due to important genetic variations. Grain sorghum appears to contain higher amounts of riboflavin than maize of the Central American region, a finding which is not in agreement with those for the grain sorghum samples studied by Tanner *et al.* (23).

The nicotinic acid content of the grain sorghums was 1.5 to 2.0 times higher than in maize (2). As in the case of the other B-complex vitamins, the variation in findings for nicotinic acid content was large; this was also true of the varieties studied by Tanner *et al.* (23).

Comparison of the results of this paper with those previously reported for maize (2,6,8,10) shows grain sorghums to be slightly higher than maize in their content of arginine, histidine, isoleucine, tryptophan, and valine, whereas their levels of leucine, lysine, methionine, phenylalanine, tyrosine, and threonine are very similar.

The isoleucine:leucine ratios in sorghum are, on the average, not as large as in maize. The ratio in maize is about 1:4; in the grain sorghums reported here, it is 1:3. Correlation coefficients were calculated from the nitrogen content and some essential amino acids. The value for nitrogen and lysine was 0.5623; nitrogen and tryptophan, 0.1046; nitrogen and isoleucine, 0.8556; nitrogen and leucine, 0.8923; and nitrogen and methionine, 0.5457. Except for lysine, the correlation coefficients were similar to those calculated for corn (7).

From these results it may be generally concluded that with the above exceptions, grain sorghums are similar to maize and should have about the same nutritive value. Comparison of the amino acid patterns of the 25 samples of sorghum reported in this paper with the amino acid pattern of the F.A.O. Reference protein (12) indicates that grain sorghum and maize are both deficient in lysine and tryptophan (20), and it also appears that grain sorghum is low in methionine. This arbitrary pattern, based on existing experimental data, is an estimate of the optimum proportions of essential amino acids in a protein for human consumption. The findings agree with reports previously published (1,11,18,21) and indicate further the similarity in nutritive value between maize and grain sorghum.

Grain sorghums are also lower in their crude caloric content than maize (2,6). The yields of the grain sorghums reported in the present paper are excellent, particularly the hybrids Texas 601-H and RS-610[6], and are higher than usually obtained for maize in the Central American region. In view of these findings, agricultural stations

[6] Mr. A. A. Arriaga; see footnote 4.

should promote an increase in production of grain sorghum, and feed manufacturers should replace at least part of the maize in the ration by grain sorghum. Moreover, controlled feeding trials with experimental animals should be carried out in order to establish the nutritional equivalence of the grain sorghum and maize. It is also necessary to determine how the usual treatments to which maize is subjected (10) will affect the nutritive value if applied to grain sorghum.

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