ARTICLES

Chemical Composition of Different Varieties of Grain Sorghum

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This paper reports on a study of the chemical and biochemical differences in five grain sorghum varieties that vary in endosperm and pericarp structures. This information may be genetically related to the breeding of grain sorghum. Fatty acid profiles revealed that the distribution of major acids (palmitic, 11–13%; oleic, 30–41%; and linoleic, 33–49%) in the five varieties was typical for sorghum but that minor components varied considerably (behenic, 0–4%; lignoceric, 0–15%; linolenic, 1.8–4.0%; 5-eicosenoic, 0.0–2.3%). Some fatty acids were absent in some varieties and present in others (arachidic, behenic, lignoceric, 5-eicosenoic, erucic). Substantial differences were noted in the mineral uptake (chromium, copper, iron, manganese, nickel) of these five varieties which were grown under agronomically similar conditions. Similarly, substantial differences were noted in the quantities of free sugars present in some of the lines. The distribution of tannins found in four protein fractions of a high tannin and a moderate tannin variety is presented.

Sorghum grain is a basic food in many parts of Africa and Asia and is the third largest cereal crop in the United States. Worldwide, it is exceeded in acreage only by wheat, rice, maize, and barley. In the United States, it is the second ranking feed grain and is cultivated primarily in the Great Plains and the Southwest. Because of improved production technology and the introduction of superior disease- and pest-resistant hybrids commercialized in the early 1960's, yield per acre in the United States has increased by more than 30% in the last 15 years (USDA, Crop Reporting Board, 1977; USDA, Statistical Reporting Service, 1974).

The genetic potential to improve the protein quality of grain sorghum was realized in the early 1970's. Several strains of sorghum with high lysine content were identified as potential material for development of commercial seed stock (Shapely, 1973; Singh and Axtell, 1973). Considerably more research, however, will be required to identify varieties more exactly and to assess the nutritional quality of new hybrids and varieties. Though primarily used as feed in the United States, the potential for wider use of sorghum in diverse foods was discussed in depth at an international symposium held in Austria in 1976 (Dendy, 1977).

The broad objective of our program is to derive new chemical and biochemical information that can contribute to both identification and further categorization of sorghum genotypes and to evaluate and compare nutritional factors in seeds from different varieties. Five varieties of grain sorghum, described in an earlier study (Neucere and Sumrell, 1979), were included in this investigation. This research is part of a broader study of these five cultivars. The present paper is concerned with proximate analyses, fatty acid profiles, free sugars, mineral content, and the distribution of tannins within four protein fractions of two varieties.

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EXPERIMENTAL METHODS

The varieties (Sullins, 1972; Sullins and Rooney, 1974) were grown in 1970 under identical agronomic conditions at College Station, Texas, and are characterized as follows: SC 301, all corneous endosperm with thin pericarp; NSA 740, floury endosperm with thick pericarp; CK 60, intermediate floury/corneous endosperm with thick pericarp; TX 615, waxy endosperm with intermediate pericarp; GA 615, high tannin content with intermediate floury/corneous endosperm.

The seeds were stored under refrigeration (4 °C) after harvesting. Protein content (nitrogen × 6.25) was determined by micro-Kjeldahl nitrogen analysis. Fat, fiber, and ash were analyzed by methods of the AACC (1962). The fatty acid profiles were determined on diethyl ether extracts by the AOAC gas chromatographic method (1975). Mineral contents were determined by atomic absorption spectrophotometry according to the method of the AACC (1962). Free sugars were determined by Enviro-Test, Inc., Westmont, IL, by the follow procedure.

Approximately 10–20 seeds were randomly poured into a mortar and ground with a pestle. The ground material was transferred to a screw-cap tube. A representative portion (0.4–0.8 g) was weighed accurately into a screw-cap centrifuge tube, and 5.0 mL of deionized water was added to each sample. (A standard consisting of the five sugars was also prepared and carried through the procedure.) The samples were shaken and allowed to contact the water overnight to extract the free sugars. The samples were centrifuged and the supernatant liquid filtered by suction and stored in screw-cap tubes. Aliquots of both sample and standard (1.0 mL) were transferred to screw-cap re-

Table I. Proximate Analysis of Five Varieties of Grain Sorghum

analysis	variety/composition[a] SC 301	NSA 740	CK 60	TX 615	GA 615
moisture	12.07	12.75	13.36	12.88	12.51
fat	3.03	3.49	3.31	2.66	3.00
protein	11.48	14.32	9.90	11.85	9.75
ash	1.71	1.83	1.35	1.49	1.37
fiber	2.10	2.58	1.91	1.39	2.29
NFE[b]	69.61	65.03	70.17	69.73	71.08
carbohydrate	71.71	67.61	72.08	71.12	73.37
carbohydrate/protein	6.25	4.72	7.28	6.00	7.53
protein/fat	3.79	4.10	2.99	4.45	3.25

[a] Percent of whole seed. [b] Nitrogen free extract.

Table II. Fatty Acid Profiles of Lipids from Five Varieties of Grain Sorghum

fatty acid	variety/composition[a] SC 301	NSA 740	CK 60	TX 615	GA 615	av[b]
myristic (14:0)	c	0.5	c	c	0.5	0.4
palmitic (16:0)	13.1	13.4	11.6	13.4	13.1	13.2
stearic (18:0)	3.0	3.6	2.9	2.9	4.0	2.0
arachidic (20:0)	c	0.9	c	c	0.5	c
behenic (22:0)	c	1.3	0.5	c	4.0	c
lignoceric (24:0)	c	1.3	0.5	c	1.5	c
total saturated	16.1	21.0	15.5	16.3	23.6	15.6
palmitoleic (16:1)	0.4	0.9	1.5	0.6	1.0	1.3
oleic (18:1)	41.3	35.0	38.5	37.4	36.2	30.5
linoleic (18:2)	38.4	36.0	40.9	43.7	33.2	49.7
linolenic (18:3)	3.0	4.0	2.0	1.8	3.5	2.0
5-eicosenoic (20:1)	0.8	2.3	1.5	0.6	2.5	c
erucic (22:1)	c	0.5	c	c	c	c
total unsaturated	83.9	79.0	84.5	83.7	76.4	83.5
unsaturated/saturated	5.2	3.8	5.5	5.1	3.2	5.4

[a] Percent of total fatty acids. [b] Wall and Blessin (1970). [c] None detected.

action vials and, by heat and air, evaporated to dryness. To each vial was added an aliquot of internal standard material (methyl undecanoate), followed by Tri-sil Z, silylating reagent for sugars. The vials were heated to 60–70 °C for approximately 1 h and cooled, and portions were injected into a gas chromatograph optimized for this assay. By reference to the internal standard and sugar standard, the five sugars were identified and the amounts of each calculated. The experiment was performed in duplicate, with the entire procedure including grinding new samples repeated. All samples were examined by gas chromatography in the same time interval, and so the response factors were averaged.

Separation of the proteins in these five varieties into four fractions by a modified procedure of Landry and Moureaux (1970) and Jambunathan and Mertz (1973) is described elsewhere (Neucere and Sumrell, 1979). The fractions of two of these varieties, NSA 740 (moderate tannin) and GA 615 (high tannin), were analyzed for tannin contents by the method of Burns (1971).

RESULTS AND DISCUSSION

The five varieties of *Sorghum bicolor* (L.) Moench studied have been used as breeding lines in the United States. The seeds, obtained from Texas A&M University, were produced under comparable agronomic conditions at College Station in 1970. Four varieties contained starch consisting of approximately 30% amylose and 70% amylopectin; the waxy type, TX 615, contained 100% amylopectin. The general anatomical structures listed here are based on an electron microscope study reported by Sullins and Rooney (1974).

Proximate analyses of these five varieties are shown in Table I. The variety with predominately floury endosperm, NSA 740, has the highest protein content. Some differences in fat, ash, carbohydrate, and fiber contents are also noted for the five varieties. Note also differences in the proportional amounts of carbohydrate/protein and protein/fat in the whole seed. These ratios along with other data may provide useful information in comparative genetic studies of seeds from different varieties.

Table III. Mineral Content of Five Varieties of Grain Sorghum

mineral	variety/content[a] SC 301	NSA 740	CK 60	TX 615	GA 615	av[b]
chromium	L[c]	L	L	30	L	0.5
cobalt	L	L	L	L	L	0.5
copper	3	8	3	4	3	5.4
iron	25	47	26	200	24	67
manganese	8	10	7	L	7	21
molybdenum	L	2	L	2	2	4.0
nickel	L	2	L	14	1	1.7
selenium	L	L	L	L	L	d
tin	L	2	L	2	2	0.5
strontium	L	d	L	d	d	d
vanadium	2	L	2	L	L	0.1
zinc	22	33	19	24	17	37

[a] Values in micrograms/gram of whole seed, dry basis. [b] Wall and Blessin (1970). [c] L = less than 1.0 μg/g of whole seed. [d] Not determined.

The content of neutral lipids in these five lines of grain sorghum ranged from 2.66 to 3.49%. The fatty acid profiles of the lipid fractions are shown in Table II. The values of major components are in general agreement with average values of other varieties (Wall and Blessin, 1970). Some minor components were not detected in some of the varieties. Two distinct levels of unsaturated/saturated ratios were present in the fatty acids of these five varieties. Values of 3.2 and 3.8 were found for GA 615 and NSA 740, respectively, and the other three varieties fell in the range 5.1 to 5.5. It is conceivable that some of these differences

Table IV. Selected Free Sugars in Five Varieties of Grain Sorghum

	variety/content[a]					
sugar	SC 301	NSA 740	CK 60	TX 615	GA 615	reported range[b]
fructose	1.67	1.12	2.32	1.80	1.06	0.05-0.38
glucose	1.78	0.68	2.00	2.94	0.87	0.04-0.34
sucrose	0.51	0.30	0.58	0.38	0.30	0.80-2.20
maltose	0.35	0.16	0.23	0.78	0.06	0.0-0.05
raffinose	0.10	0.03	0.03	0.11	0.05	0.10-0.13
total	4.41	2.29	5.16	6.01	2.34	0.99-3.10

[a] Percent of whole seed excluding moisture-average value of two samples from each variety. [b] Wall and Blessin (1970).

be connected to genetic characteristics and have value as chemical markers in breeding programs.

Contents of several minerals known to be essential in human nutrition are shown in Table III. Some deviation from average values was observed. Contents of chromium, iron, and nickel, for example, were much higher in TX 615 than in the other four varieties, which were within the normal range (Wall and Blessin, 1970). Substantial differences in contents of other metals such as copper and zinc were also observed among these varieties. Because many of these essential minerals are located in the pericarp–aleurone area of the seed, perhaps further analyses of component parts will give more exact information on comparative mineral contents.

A comparative analysis of five free sugars in these five varieties is shown in Table IV. In all the samples fructose and glucose comprise the highest contents of free sugars analyzed. The values are higher than those reported by earlier investigators (Wall and Blessin, 1970). The relative amounts of sucrose are somewhat lower and contents of maltose are higher than what has been reported as average values. NSA 740, the all floury variety, contained about one-half the amount of total free sugars as did the other three low-tannin varieties. However, GA 615, the high-tannin variety with intermediate floury-corneous endosperm, contained quantities of all five sugars similar to those found in NSA 740. Because the crops were produced under identical agronomic conditions, we assume that stages of maturation were the same for all of the seed samples.

The separation of the protein into four fractions describing amino acid profiles is reported elsewhere (Neucere and Sumrell, 1979). In the current work, the tannin content of these fractions and the tannin/protein ratio were investigated in the high-tannin variety, GA 615, and a moderate-tannin variety, NSA 740. The data are presented in Table V. The fractions varied considerably in protein content, and the protein content of analogous fractions from the two varieties also differed considerably. Extraction of the albumin (fraction 1) and globulin (fraction 2) proteins was poor in the high-tannin GA 615, and as might be expected, the protein extracted was high in tannin and tannin–protein complexes. The major portion of the tannins was present in the prolamin (fraction 3) and glutelin (fraction 4) fractions in both varieties. A study by Guiragossian et al. (1978) showed that the ratio of kafirin (prolamin) to glutelin was higher for normal sorghum than for high-tannin cultivars. This is in accordance with the present study. And as pointed out by these authors, protein constituents of identical fractions vary quantitatively rather than qualitatively. Other studies involving dehulling of high- and low-tannin sorghums suggested strong interactions between the prolamin (kafirin) proteins and the tannins (Chibber et al., 1978).

Table V. Relative Tannin Contents in Whole Seed and in Protein Fractions of a Moderate (NSA 740) and High (GA 615) Tannin Sorghum Variety[a]

fraction	% protein	% protein extracted	mg of catechin/ 100 mg dry wt	μg of tannins/ mg of protein[b]
NSA 740				
whole seed	14.3		0.48	34
defatted seed	17.1	59.0		
fraction 1	16.0[c]	25.5[d]	0.12	8
fraction 2	29.4	15.1	0.11	4
fraction 3	76.3	54.8	1.1	14
fraction 4	30.6	4.5	1.4	46
GA 615				
whole seed	9.8		2.8	286
defatted seed	11.5	69.0		
fraction 1	5.6[c]	4.3[d]	3.0	536
fraction 2	3.0	1.0	1.4	467
fraction 3	86.3	60.3	12.0	174
fraction 4	36.3	34.3	12.0	331

[a] Isolation procedure by Neucere and Sumrell (1979). [b] Micrograms of tannins = micrograms of catechin equivalent. [c] Of freeze-dried fractions. [d] Percent of recovered protein in each fraction.

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