Note on the Soluble Sugars of Sorghum[1]

V. SUBRAMANIAN, R. JAMBUNATHAN, and S. SURYAPRAKASH, International Crops Research Institute for the Semi-Arid Tropics, Patancheru P.O. 502 324, Andhra Pradesh, India
Cereal Chem. 57(6):440-441

Sorghum (*Sorghum bicolor (L.) Moench*) is a major food crop ranking fifth in world grain production. It is an important source of calories and protein for a large segment of the human population in the semiarid tropics. Although information on proteins, amino acids, and starch content of sorghum is available (Rooney 1973), relatively little is known about the nature of sugars in sorghum (Watson and Hirata 1960). In our institute, studies on the relationship of the physicochemical characteristics of sorghum meal with chapati-making characteristics are in progress. Because sugars may be one of the factors imparting characteristic taste and flavor to the food products made from sorghum, the present study was undertaken to identify a suitable procedure for examining the nature of sugars in sorghum. The distribution pattern of sugars in 10 sorghum cultivars is reported in this communication.

MATERIALS AND METHODS

Ten sorghum cultivars (Table I), grown at the International Crops Research Institute for the Semi-Arid Tropics Center, Patancheru (near Hyderabad), and representing a range of endosperm texture from corneous to floury, were selected for this study. Four of the cultivars (CSH-8, IS-11167, IS-11758, and RY-49) were grown during the post-rainy season of 1976, and the remaining six were grown during the post-rainy season of 1977. The grains were ground in a Udy cyclone mill to pass through a 60-mesh sieve and were defatted using *n*-hexane in a Soxhlet apparatus.

Isolation of Sugars

Sorghum meals were extracted with 80% ethanol for 5 hr in a Goldfisch extraction apparatus. The quantity of soluble sugars in the extract was estimated by the phenol-sulphuric acid method of Dubois et al (1956).

Column Chromatography

The procedure of John et al (1969) for separating sugars was slightly modified. A slurry of Biogel P-2 (400-mesh) was boiled, cooled, and, after degasification, packed into a jacketed column (57 × 2.6 cm). The temperature of the column was maintained at 50°C. An appropriate volume of sugar extracts containing 1 mg of soluble sugars was applied on the column, and the sugars were eluted with distilled, deionised water at 50°C. Two-milliliter fractions were collected at a flow rate of 38 ml/hr, and sugars were detected by use of the phenol-sulphuric acid reagent. The individual sugar peaks were identified by the independent application of known quantities of each of the standard sugars (stachyose, raffinose, sucrose, glucose, and fructose), and the sugars were eluted through the column. A mixture of these sugar solutions was also applied and eluted through the column in order to compare the elution profile obtained with individual sugars. The sugars in the samples were identified by reference to the elution pattern of standard sugars. For quantitative estimation of individual sugars, each fraction eluting from the column was individually analyzed. The absorbance of each of the fractions was plotted, and the peak areas were compared with the areas of their respective standards.

Thin-Layer Chromatography

Sugars were separated on thin-layer chromatography (TLC) plates prepared using aqueous silica gel slurry (40 g/100 ml). A solvent system consisting of chloroform, acetic acid, and water (3.0:3.5:0.5, v/v) was used as described by De Stefanis and Ponte (1968). The sugar spots were detected using diphenylamine-aniline reagent.

RESULTS AND DISCUSSION

The total sugar contents of the 10 sorghum cultivars varied from 1.30 to 5.19%. The high lysine Ethiopian lines (IS-11167 and IS-11758) had higher sugar content (Table I). Neucere and Sumrell (1980) reported that free sugar content in five varieties of sorghum varied from 2.34 to 6.01%. Sorghum seeds with sugary endosperms have been reported to contain at least twice the quantity of sugars that normal seeds contain (Karper and Quinby 1963). Edwards and Curtis (1943) reported that in a study of 26 sorghum samples, sugar content varied from 0.81 to 1.59%.

Addition of phenol-sulphuric acid reagent to sugar extracts produced a golden yellow color. However, in the case of sugar extracts from IS-11167 and IS-11758, addition of the reagent produced a pink color that later turned to golden yellow. A similar color response was observed on addition of the reagent to each of the sugar fractions of IS-11167 and IS-11758 eluted from the Biogel column. Addition of sucrose or tannic acid to the sugar extract of a normal sorghum (CSH-8) did not produce a similar response when tested with phenol-sulphuric acid reagent. This phenomenon requires further detailed investigation. Five sugar components were identified when the soluble sugar extracts of sorghum were eluted from the Biogel column. Stachyose, raffinose, and sucrose were eluted in that order, followed by glucose and fructose, which were eluted together as a single peak. The presence of the sugars stachyose, raffinose, sucrose, glucose, and fructose in the ethanol extracts of the meals from the 10 cultivars was also confirmed by TLC, using the respective standard sugars. Further, for one of the samples (CSH-6), the fractions of individual sugar peaks eluted from the column were pooled. Each of the fractions was evaporated in vacuo and then dissolved in a minimum quantity of water. The concentrated fractions were then spotted on TLC plates, along with their respective standards. The identity of the individual sugars in the fractions eluted from the column was confirmed by this procedure. The pooled fourth fraction showed the presence of both glucose and fructose by this procedure as well.

Sucrose is the predominant sugar in the sorghum grains. The proportion of sucrose ranged from 68.7 to 82.7% of soluble sugars

TABLE I
Soluble Sugars Composition of Sorghum Grains[a]

Cultivars	Total Soluble Sugars (%)	Stachyose (%)	Raffinose (%)	Sucrose (%)	Glucose + Fructose (%)
CSH-8	1.34	0.08 (6.0)[b]	0.12 (9.1)	0.92 (68.7)	0.22 (16.2)
IS-11167	5.19	0.16 (3.1)	0.39 (7.5)	3.90 (75.1)	0.74 (14.3)
IS-11758	4.43	0.21 (4.7)	0.39 (8.7)	3.42 (77.1)	0.42 (9.5)
RY-49	2.00	0.07 (3.4)	0.24 (12.1)	1.49 (74.5)	0.20 (10.0)
Karad	1.50	0.05 (3.3)	0.19 (12.5)	1.16 (76.9)	0.11 (7.3)
CS-3541	1.39	0.04 (3.1)	0.10 (7.4)	1.15 (82.7)	0.09 (6.8)
M.35-1	1.40	0.07 (4.8)	0.23 (16.4)	0.99 (70.5)	0.12 (8.3)
P-721	2.67	0.13 (4.9)	0.26 (9.8)	1.84 (68.7)	0.44 (16.6)
E.35-1	1.30	0.11 (8.2)	0.18 (14.2)	0.93 (71.9)	0.07 (5.7)
CSH-6	1.32	0.08 (5.8)	0.16 (12.1)	1.03 (77.7)	0.06 (4.4)

[a] Moisture-free basis; each value represents the mean of two independent determinations.
[b] Figures in parentheses are expressed as percent of total sugars.

[1] Submitted as Journal Article 129 by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT).

0009-0352/80/06044002/$03.00/0

TABLE II
Sugar Composition of Wheat, Maize, Barley, Oat, and Sorghum (g/100-g sample)

Cereal	Raffinose	Sucrose	Maltose	Fructose	Glucose
Wheat flour[a]	0.05–0.43	0.16–0.60	0.07–0.09	0.02–0.03	0.04–0.06
Maize[b]	0.20–0.30	0.70–1.25	···	0.20–0.26	0.03
Barley[c]	0.14–0.83	0.34–1.69	0.14	0.03–0.16	0.02–0.09
Oat flour[a]	0.16–0.26	0.40–0.63	0.01–0.03	0.02–0.05	0.06–0.07
Sorghum[d]	0.10–0.13	0.80–2.20	0.02–0.05	0.05–0.38	0.04–0.34
Sorghum[e]	0.03–0.11	0.30–0.58	0.06–0.78	1.06–2.32	0.87–2.94

[a] MacArthur and D'Appolonia 1979.
[b] Cerning 1970.
[c] Kent 1975.
[d] Watson and Hirata 1960.
[e] Neucere and Sumrell 1980.

in the sorghum cultivars (Table I). While Watson and Hirata (1960) reported sucrose to be the predominant sugar of sorghum, a recent report by Neucere and Sumrell (1980) showed fructose and glucose to be the major components. Koch et al (1951) and Saunders and Walker (1969) also reported sucrose as the major component of sugar in wheat and wheat bran, respectively. Stachyose content as percent of sample was particularly high in the two Ethiopian lines, IS-11167 and IS-11758, although E.35-1 recorded the highest proportion of stachyose when expressed as percent of total sugars. Rooney and Clark (1968) reported the presence of trace amounts of stachyose in sorghum.

Raffinose content in sorghum ranged between 7.4 and 16.4% of total sugars. MacArthur and D'Appolonia (1979) reported the presence of raffinose in wheat. The quantity of glucose and fructose present in sorghum samples ranged from 4.4 to 16.6% of the total sugar content. Maltose was not detected in the sorghum samples. This was verified by adding reagent grade maltose to the sugar extracts of CSH-8 and M.35-1. The concentration of maltose added was approximately equivalent to one hundredth of the concentration of sucrose in the sugar extracts. The sugar extracts and sugar extracts containing maltose were separated by TLC technique. Although maltose was not detected in the sugar extracts of samples, it was clearly visible in the sugar extracts containing maltose. Maltose was reported to be present in small quantities (0.05%) in sugary sorghum (Watson and Hirata 1960). The absence of maltose has also been reported in proso and foxtail millets (Becker and Lorenz 1978).

The sugar composition of various cereals is shown in Table II. Sucrose has been reported to be the major component of sugars in all the cereals except in sorghum (Neucere and Sumrell 1980). Raffinose content is comparatively higher in barley than in other cereals. The quantity of maltose is generally low in cereals and the quantities of glucose and fructose showed a wide variation among the cereals.

CONCLUSIONS

Soluble sugars from 10 sorghum cultivars were separated using a Biogel column. Each cultivar contained five different sugars, namely, stachyose, raffinose, sucrose, glucose, and fructose. Although the percentage distribution of each of these sugars varied considerably within each cultivar, sucrose was the predominant sugar in all the cultivars.

ACKNOWLEDGMENTS

We thank D. S. Murthy and N. Seetharama for providing the samples and the staff of the Information Services for their editorial assistance.

LITERATURE CITED

BECKER, R., and LORENZ, K. 1978. Saccharides in proso and foxtail millets. J. Food Sci. 43:1412.

CERNING, J. 1970. Contribution à l'étude de l'évolution de la composition glucidique des céréales au cours de leur maturation: Mâis, blé, orge. Thèse de Doctorat de l'Université de Lille. No. 80.

De STEFANIS, V. S., and PONTE, J. G. 1968. Separation of sugars by thin-layer chromatography. J. Chromatogr. 34:116.

DUBOIS, M., GILLES, K. A., HAMILTON, J. K., REBERS, P. A., and SMITH, F. 1956. Colorimetric method for determination of sugars and related substances. Anal. Chem. 28:350.

EDWARDS, W. M., and CURTIS, J. J. 1943. Grain sorghums, their products and uses. ACE-193, NM-229. Northern Regional Research Lab., U.S. Dept. Agric. Peoria, IL.

JOHN, M., GOTZ, T., and DELLWEG, H. 1969. Quantitative chromatography of homologous glucose oligomers and other saccharides using polyacrylamide gel. J. Chromatogr. 42:476.

KARPER, R. W., and QUINBY, J. R. 1963. Sugary endosperm in sorghum. J. Heredity 54:121.

KENT, N. L. 1975. Technology of Cereals with Special Reference to Wheat, p. 49. Pergamon Press: Oxford.

KOCH, R. B., GEDDES, W. F., and SMITH, F. 1951. The carbohydrates of the gramineae: I. The sugars of the flour of wheat (Triticum vulgare). Cereal Chem. 28:424.

MacARTHUR, L. A., and D'APPOLONIA, B. L. 1979. Comparison of oat and wheat carbohydrates. I. Sugars. Cereal Chem. 56:455.

NEUCERE, N. J., and SUMRELL, G. 1980. Chemical composition of different varieties of grain sorghum. J. Agric. Food Chem. 28:19.

ROONEY, R. W. 1973. A review of the physical properties, composition and structure of sorghum grain as related to utilization. Pages 316-342 in: Industrial Uses of Cereals. Pomeranz, Y., ed. Am. Assoc. Cereal Chem.: St. Paul, MN.

ROONEY, L. W., and CLARK, L. E. 1968. The chemistry and processing of sorghum grain. Cereal Sci. Today 13:258.

SAUNDERS, R. M., and WALKER, H. G. 1969. The sugars of wheat bran. Cereal Chem. 47:85.

WATSON, S. A., and HIRATA, Y. 1960. Carbohydrates in grain sorghum kernels. Sorghum Newsl. 3:7.

[Received Feb. 25, 1980. Accepted July 28, 1980]