Neutral Sugars of Hemicellulose Fractions of Pith from Stalks of Selected Plants

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Cereal Chem. 56(5):441-442

ABSTRACT

Pith from stalks of corn, sweet sorghum, sugarcane, and sunflowers was fractionated into its hemicellulose components, and the neutral sugar content of each material was determined by gas-liquid chromatography. To compare pith with other components of the stalk, rind and fibrovascular bundles from corn were fractionated and analyzed in the same manner.

Recent developments have renewed interest in the composition and uses of hemicelluloses. The alleged carcinogenic properties of some synthetic sweeteners have prompted a search for sucrose substitutes of natural origin. Hemicellulose, which is rich in a number of neutral sugars, is a promising source of xylose, which can be modified to give xylitol, a sugar substitute.

Fiber in the human diet has a definite effect on bowel function, and lack of fiber in the diet may cause some diverticular diseases. Recent evidence suggests that dietary fiber might act as a protection against colonic cancer.

The stalks of agricultural plants are a readily available source of both fiber and hemicellulose. Corn, sweet sorghum, sugarcane, and sunflowers are members of a group of plants with densely packed rind fibers that enclose the major cross-sectional area of the plant, composed of pith cells through which run fibrovascular bundles and ducts. These plants contain 25–50% pith by weight and a larger percentage by volume. The soft, very white, finely divided nature of pith holocellulose makes it especially attractive as a food component or as a starting material in the production of sugars.

As part of an ongoing research program to use agricultural residues, we isolated the piths from stalks of corn, sweet sorghum, sugarcane, and sunflowers. Each pith was fractionated into its hemicellulose components, and the neutral sugar content of each material was determined. To compare pith with other components of the stalk, we fractionated rind and fibrovascular bundles from corn and analyzed them in the same manner.

MATERIALS AND METHODS

Corn and sunflower stalks were grown locally. Sugarcane was obtained from J. D. Mills of Canal Port, FL, and sorghum pith was supplied by Bruce J. Lime of Westlaco,TX.

The core was scraped away from the rind of stalks of corn, sugarcane, sweet sorghum, and sunflowers, and the pith was separated from the fibrovascular bundles by fine grinding and blowing off the lighter pith. The sugar had to be thoroughly washed from the cane and sorghum before grinding. Air separations were done by the method of Clark et al (1973).

Lipid was removed from pith by overnight extraction with 67.6% benzene and 32.4% ethyl alcohol (Kurth 1939). Holocellulose was prepared by extracting lignin from the defatted pith with chlorous acid at 74°C. Delignification was necessary to obtain complete recovery of sugars. This is essentially the method of Whistler et al (1948) except that larger volumes of liquid were needed because of the lightness and great water absorption of pith. Lignin was analyzed by the methods of Bagby et al (1971, 1973). The delignified material (holocellulose) was then fractionated into cellulose, hemicellulose A, and hemicellulose B. Hemicellulose was extracted from holocellulose with 10% sodium hydroxide at room temperature. The alkali-insoluble material, which is the cellulose fraction, was separated by filtration, washed with water and acetone, and air dried. Hemicellulose A was precipitated from the alkaline solution by bringing the pH to 5 with acetic acid, and hemicellulose B was isolated by adding three volumes of ethyl alcohol (Whistler and Feathers 1965).

The neutral sugar and cellulose content of each fraction was determined as described by Sloneker (1971). In this method, the sugar content of the whole fraction is first determined by gas-liquid chromatography. A second aliquot is then extracted with a 9:1 mixture of 80% acetic acid and concentrated nitric acid to remove all noncellulosic material; the insoluble residue is analyzed similarly to determine the amount of glucose (cellulose) in the fraction. The difference between the two glucose figures is considered to be noncellulose glucose, a part of the hemicellulose. This is the "glucose" figure listed in Table I.

RESULTS AND DISCUSSION

Table I lists the neutral sugar composition of each fraction, calculated on dry weight basis. The ash content of each fraction is also given.

As explained, the "glucose" listed in Table I is the glucose that was dissolved by acetic/nitric acid reagent and therefore assumed to be hemicellulose. However, the data show that a quarter of the

[1]Mention of firm names or trade products does not imply their endorsement or recommendation by the USDA over other firms or similar products not mentioned.

TABLE I
Neutral Sugar Content of Delignified Stalk Components

Sample	Percent of Total Sample Weight							
	Arabinose	Xylose	Mannose	Galactose	Glucose	Cellulose	Ash	Total Aldose
Pith								
Corn	2.9	18.6	t[a]	t	13.5	27.8	4.4	63.1
Sorghum	3.8	15.6	···	···	35.3	21.3	2.2	76.0
Sugarcane	3.3	24.9	t	t	13.4	25.1	0.7	66.6
Sunflower	1.6	1.1	1.0	0.5	15.7	15.8	17.0	35.6
Fiber								
Corn[b]	2.0	19.3	···	t	12.0	32.3		65.6
Corn[c]	2.4	13.9	···	t	15.5	20.3	3.5	51.9
Sorghum[b]	3.9	15.4	···	1.1	30.3	26.2	1.5	76.9
Sugarcane[b]	2.6	24.0	···	0.3	10.8	31.4	1.7	69.2
Sunflower[b]	2.0	2.0	2.0	2.6	4.5	24.1	19.9	37.0
Holocellulose[d]								
Corn	3.9	27.1	t	···	14.1	38.5	2.2	84.1
Sorghum	4.2	17.1	···	···	23.4	28.2	2.0	73.5
Sugarcane	4.0	26.3	···	···	7.7	41.8	1.9	79.8
Sunflower	2.0	5.4	3.6	1.3	15.7	25.0	7.6	53.1
Corn fiber[c]	4.5	25.4	0.2	0.5	3.6	43.5	1.6	77.7
Hemicellulose A								
Corn	4.3	70.5	···	···	10.9	6.3	7.8	91.9
Sorghum	4.4	46.5	···	1.2	20.3	5.5	3.6	77.9
Sugarcane	3.5	60.9	t	t	6.1	8.8	6.3	79.7
Sunflower	0.9	5.8	21.8	···	19.0	45.4	12.4	92.8
Corn fiber[c]	4.8	64.6	t	0.7	4.4	1.8	6.4	76.2
Hemicellulose B								
Corn	9.7	43.8	1.0	3.6	12.1	···	9.7	70.4
Sorghum	8.5	18.1	t	3.4	47.7	···	5.9	78.0
Sugarcane	9.0	33.0	2.7	3.6	13.9	···	10.8	62.3
Sunflower	3.4	24.5	12.6	3.6	11.8	2.1	3.9	58.1
Corn fiber[c]	13.9	40.8	···	3.4	11.3	···	15.3	69.5
Cellulose								
Corn	1.0	3.2	0.9	0.5	24.9	71.6	1.4	102.0
Sorghum	1.3	4.0	t	t	22.6	63.0	0.9	90.5
Sugarcane	···	3.4	t	t	11.4	62.8	13.5	78.1
Sunflower	2.2	1.7	0.6	1.9	27.9	21.3	27.8	55.9
Corn fiber[c]	1.5	4.6	···	···	22.4	70.2	1.8	98.7

[a] t = trace ($< 0.5\%$).
[b] Fibrovascular bundles.
[c] Fiber of rind and core.
[d] Less than 0.8% lignin.

cellulose fraction is soluble in that reagent. This indicates that a considerable amount of the "glucose" in various fractions may arise from material in the cellulose fraction, and the isolated hemicellulose fractions are probably contaminated with cellulose. The methods used to separate cellulose from hemicellulose of plant tissues are crude, and a clean separation would not be expected.

Because the pith and fibrovascular bundles of a given plant have essentially the same sugar composition, the pith would not have to be separated from the bundles if the research interest was primarily sugar. The rind of corn (the only plant rind analyzed) and its fractions have approximately the same neutral sugar content as the core, except that the hemicellulose B of rind is especially rich in arabinose. Again, if sugars are the primary concern, the whole stalk could be used. If the products are to go into food, feed, or certain industrial applications, however, separation might be desirable.

Of the plants examined, corn and sugarcane have the highest xylose content, but sorghum also has a significant amount of this sugar. Sunflower differs, having very little xylose but relatively large amounts of mannose and galactose, which are present in only trace amounts in the other plants.

In corn, sorghum, and sugarcane, xylose is concentrated in the hemicellulose A fraction, whereas the amounts of the other sugars are greater in hemicellulose B. Xylose is by far the major component of the hemicellulose A fraction of these plants. If much of the "glucose" of the hemicellulose is actually cellulose, hemicellulose A of corn, sorghum, and sugarcane is primarily a xylan. In contrast, sunflower has little xylose, and most of it is in the B rather than the A fraction. Hemicellulose A of sunflower contains a large amount of mannose, and all of the sunflower fractions have higher ash content than do those of other plants.

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[Received February 12, 1979. Accepted April 20, 1979]