Monosaccharides Produced by Acid Hydrolysis of Selected Foods, Dietary Fibers, and Fecal Residues from White and Whole Wheat Bread Consumed by Humans

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Samples of celluloses, xylans, dry beans, brans (wheat, corn, rice, sorghum), white bread, and whole wheat bread were hydrolyzed directly with trifluoroacetic acid (TFA). Identification and quantitation of the monosaccharides produced by this hydrolysis characterized the hemicelluloses present; this is important in correlating gastrointestinal responses attributable to specific hemicelluloses. Direct TFA hydrolysis of fecal samples provided the same information for ingested hemicelluloses that survived digestion. Results for bread samples were compared to those from fecal material from humans consuming these breads. Compared to a diet in which no bread was consumed, one-fourth of the acid hydrolyzable hemicelluloses from whole wheat bread and none from white bread were recovered in the fecal material. Arabinose and xylose from whole wheat bread hemicelluloses were not recovered in the same ratios as they were fed.

Hemicelluloses, including xylans, mannans, galactans, etc., comprise a principal and important component of food dietary fiber. These polysaccharides are not digested in the upper gastrointestinal tract and enter the colon where they have effects on nutrient availability and physiologically active substances (e.g., vitamins, minerals, bile acids, cholesterol, etc.). They are also fermented by intestinal microflora to volatile fatty acids (VFA), hydrogen, methane, and carbon dioxide (Vahouny, 1985; Cummings, 1982, 1983). Fermentation in the colon has been implicated in elevating VFA absorption and eventually cholesterol levels in the blood and in influencing colon function, including flatulence and regularity. Chemical analysis that determines monosaccharide composition is essential in order to relate specific hemicelluloses to these physiological responses.

Hemicelluloses can be identified and characterized by gas chromatography of derivatized carbohydrate residues liberated by mild acid hydrolysis. Sulfuric and trifluoroacetic acids have been used to hydrolyze hemicellulose (Englyst and Cummings, 1984; Fengel and Wegner, 1979). Previously we showed that trifluoroacetic acid (TFA) hydrolysis of human fecal samples collected after ingestion of different dietary fibers produced monosaccharides that were related to the fibers ingested (Olson et al., 1983). This study extends these investigations to the hemicelluloses in wheat bread, a complex food. In Western cultures wheat breads are a major source of dietary fiber (Becker et al., 1986; Englyst et al., 1983; Moss and Mugford, 1986; Wenlock et al., 1985).

The objectives of the present study were (1) to compare the monosaccharide composition of hemicelluloses in selected foods and food components by direct acid hydrolysis, (2) to compare the monosaccharide composition of hemicelluloses in white and whole wheat bread that survive fermentation in the colon, and (3) to predict how much of the hemicellulose in the breads was fermented.

MATERIALS AND METHODS

Materials. Samples were obtained as follows: Whatman filter paper, local supplier; Sigmacell, α-cellulose, and xylan, Sigma Chemical Co., St. Louis, MO 63178; Avicel, FMC Corp., Food and Pharmaceutical Products Division, 2000 Market St., Philadelphia, PA 19103; Alphacel and xylan, ICN Nutritional Biochemicals, Cleveland, OH 44128; Keycel, ITT Paniplus, 100 Paniplus Roadway, Olathe, KS 66061; Fitrate, Dawson Food Ingredients, 7901 Flying Cloud Dr., Minneapolis, MN 55344; Nitrisoy fiber, Archer Daniels Midland Co., Box 1470, Decatur, IL 62525; dry beans, local suppliers; sorghum bran fractions, gift from A. Shephard, WRRC, Albany, CA 94710; corn bran, A. E. Staley Manufacturing Co., Decatur, IL 62525; corn bran, Quaker Oats, Chicago, IL 60654; rice brans, gift from R. Sayre, WRRC; wheat brans, American Association of Cereal Chemists. White and whole wheat flours were commercially milled from the same lot of hard red spring wheat. Breads were baked from the flours by a local bakery and frozen until used. Samples of bread were freeze-dried and blended for analysis.

Water used in all steps and reagents was purified by a Milli-RO/Milli-Q system (Millipore Corp., Milford, MA 01757). Trifluoroacetic acid (Sequanal Grade, 13 N, Pierce Chemical Co., Rockford, IL 61105) was diluted to 2.0 N. L-Rhamnose, D-arabinose, D-xylose, D-mannose, D-galactose, and D-glucose (Sigma) were dried under vacuum at 70 °C. Acetic anhydride, pyridine, and anhydrous methanol were ACS reagent grade from various suppliers. Sodium borohydride (powder) was obtained from Alfa Products-Ventron, Danvers, MA.

Hydrolyses. Samples were analyzed in duplicate following procedures described by Albersheim et al. (1967) with modifications. Enough dry food, fiber, isolate, or fecal material was weighed into glass screw-top vials (Kimble, Owens, IL) to provide 2–6 mg of hydrolyzable carbohydrate. This amounted to 3–10 mg of dry food (lyophilized or air-dried) or 10–20 mg of homogenized, lyophilized fecal sample. One milliliter of 2.0 N TFA was added to the vial, which was then sealed with a cap with a Teflon-faced hard rubber liner (Pierce) and heated to 121 °C for 1.0 h. After cooling to 25 °C, contents of the vials were dried at 50 °C under dry nitrogen. Monosaccharides were reduced with 1.0 mL of a 10 mg/mL solution of sodium borohydride ($NaBH_4$) with one drop of 3.75 N NaOH per vial. After 1 h at 25 °C excess borohydride was destroyed by adding glacial acetic acid dropwise until effervescence ceased. Solutions were evaporated to dryness at 80 °C under dry nitrogen, and remaining borate was removed by additions of 1 mL of dry methanol followed by evaporation to dry-

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Table I. Anhydro Monosaccharides from TFA Hydrolysis of Cellulose[a]

no.	source	Rh	Ar	Xy	Ma	Ga	Gl	total[a]
1	Whatman 1 filter paper	N	N	0.1	N	N	1.7	1.8
2	Sigmacell 20 lot 18c-0373	N	N	0.2	tr	N	2.6	2.8
3	Avicel PH-101	N	N	0.2	tr	N	0.8	1.0
4	Avicel RC-591	N	N	0.4	tr	N	2.8	3.2
5	Alphacel (ICN) lot 5900	N	tr	4.6	tr	N	6.3	10.9
6	Alphacel (ICN) lot 7179	N	N	5.5	0.2	N	6.2	11.9
7	Keycel lot 11232	N	N	2.6	1.3	N	5.1	8.0
8	α-cellulose (Sigma) lot 29C-0394	N	N	1.4	0.3	N	3.2	4.9

[a] As percentage of dry sample. Key: Rh = rhamnose, Ar = arabinose, Xy = xylose, Ma = mannose, Ga = galactose, Gl = glucose; N = none detected; tr = detected but too small to quantitate.

Table II. Anhydro Monosaccharides from TFA Hydrolysis of Xylan[a]

no.	source	Rh	Ar	Xy	Ma	Ga	Gl	total[a]
1	xylan (ICN) lot 5611	N	0.2	24.9	38.5	N	13	76.6
2	xylan (ICN) lot 7607	N	0.2	17.2	27.5	N	9.4	54.3
3	xylan (ICN) lot 8478	N	0.1	16.8	15.4	N	4.5	36.8
4	xylan (Sigma) lot 97C00661	N	4.9	32.6	tr	0.5	5.1	43.1
5	xylan (Sigma) lot 128C03641	0.2	0.1	30.0	0.1	0.1	0.1	30.6

[a] As percentage of dry sample. Key: Rh = rhamnose, Ar = arabinose, Xy = xylose, Ma = mannose, Ga = galactose, Gl = glucose; N = none detected; tr = detected but too small to quantitate.

ness. Alditols were acetylated by adding 1.0 mL of an acetic anhydride/pyridine mixture (10:1, v/v), capping the vial, and heating at 121 °C for 2 h. Samples were mixed (vortex mixer) and centrifuged 20 min at 7000*g*. Aliquots of the supernatants were transferred to autosampler vials for analysis by gas chromatography.

Gas Chromatography. Samples were injected with a Teflon-tipped plunger syringe (Dynatech Precision Sampling, Baton Rouge, LA) in an autosampler (7671A, Hewlett-Packard Corp., Avondale, PA) connected to a 5880 GC (Hewlett-Packard) equipped with a capillary injector at 200 °C, operated in the split injection mode (40:1). The alditol acetates were separated on a Supelco (Bellefonte, PA) SP-2330 coated (68% (cyanopropyl)methylsilicone) fused silica column, 0.24-mm i.d. by 30-m length. Temperature program: initial temperature of 170 °C for 1 min; 5 °C/min increase to 210 °C; 2 °C/min increase to 225 °C; 1 °C/min increase to 235 °C; hold for 10 min. The flame ionization detector was operated at 250 °C with nitrogen make-up gas to supplement the helium carrier gas. Gas chromatography of each duplicate hydrolyzed sample was done in triplicate and quantitated with constants obtained from standard mixtures of monosaccharides prepared by the same method and at the same time as the samples. Mean values for monosaccharides are reported as anhydro sugars.

In Vivo Study. Six normal young men with no histories of gastrointestinal disorders or food allergies were subjects in an 84-day metabolic ward study. The study, a crossover experimental design, was divided into test periods of 24, 24, 12, and 24 days. Diets contained the required levels of all nutrients. Meals were served at equally spaced intervals 4 times/day. Additional details concerning the diets will be published elsewhere (Turnlund et al., in preparation). Basal egg albumin diet, containing no bread, was fed to all subjects during the first and third period and white and whole wheat bread diets during the second and fourth periods. Bread provided 40 g of protein in diets providing 9.0–9.4 g of nitrogen/day, with egg albumin supplying the remainder. The bread diets included 1 lb fresh weight of white or whole wheat bread/day.

Fecal collections from each subject were frozen in 3-day pools. The last two pooled samples of each test period were blended, combined, freeze-dried, weighed, and reported as grams of dried feces/day per subject. Aliquots of these samples were analyzed for each of the six subjects.

RESULTS AND DISCUSSION

Monosaccharides Produced by TFA Hydrolysis of Dietary Fiber Hemicelluloses. Monosaccharides produced by this hydrolysis were characteristic of the food or fiber under study and provided information about the hemicellulose content of the fiber. Standard deviations for monosaccharide analyses were ±3% of the value or ±0.05% of the sample, whichever is larger.

Celluloses. Hydrolysis of the first four samples reported in Table I produced the smallest amounts of monosaccharides, 0.8–2.6% glucose, less than 0.5% xylose, and trace amounts of mannose. Whatman filter paper produced the smallest amount of glucose. The next four samples produced larger amounts of glucose (3.6–6.3%) and xylose (1.4–5.5%). A significant amount of mannose (1.3%) was obtained from Keycel.

Small amounts of cellulose may be hydrolyzed by these procedures (Fengel and Wegner, 1979), and the glucose produced from the first four samples may provide an upper estimate of how much. Subtracting this amount of glucose from what was produced by samples 5–8 leaves 1.2–4.3% glucose, which, together with the xylose and mannose present, is probably from hemicelluloses in the cellulose preparations as they are obtained from wood pulp. These hemicelluloses may be fermentable in the colon.

Xylans. Xylan is another preparation obtained from wood that has been used in feeding experiments to show the differences between hemicellulose, a potentially fermentable dietary fiber, and cellulose, reportedly less fermentable (Slavin et al., 1981). Monosaccharides from the hydrolysis of xylan samples, including different lots from the same source, produced different amounts of monosaccharides (Table II). The xylans are interesting because the xylose content did not always predominate. The wood fiber source determines the composition of these preparations and whether they are xylans or mannans (Aspinall, 1980). These differences can only be determined by chemical analysis, which are important in relating results from feeding studies to the identity of the samples fed.

Dry Beans. Prior to hydrolysis, beans were blanched and extracted with hot water to remove soluble sugars, including α-galactosides (Olson et al., 1982). The galactose content reported is therefore from galactose-containing

Table III. Anhydro Monosaccharides from TFA Hydrolysis of Dry Beans and Soy Fibers[a]

no.	source	Rh	Ar	Xy	Ma	Ga	Gl	total[b]
				Dry Beans				
1	CA sm white	0.1	5.9	1.2	0.8	1.2	53	62.2 (9.2)
2	beans, red kidney	0.1	4.9	0.9	0.6	1.1	50	57.6 (7.6)
3	beans, Jacobs cattle	0.1	5.3	0.9	0.7	1.4	52	59.4 (7.4)
4	beans, blackeye	0.2	3.0	0.2	0.2	1.0	65	69.6 (4.6)
5	beans, garbanzo	0.2	4.6	0.1	0.2	1.0	63	69.1 (6.1)
6	beans, soy	0.2	1.9	0.6	0.6	4.0	1.5	8.2
				Soy Fibers				
7	fitrate, Dawson	0.7	7.9	2.6	0.3	14.6	3.4	29.5
8	Nutrisoy fiber E ADM	0.8	3.1	4.3	3.2	2.0	1.3	14.7

[a] As percentage of dry sample. Key: Rh = rhamnose, Ar = arabinose, Xy = xylose, Ma = mannose, Ga = galactose, Gl = glucose; N = none detected; tr = detected but too small to quantitate. [b] Numbers in parentheses are totals excluding glucose.

Table IV. Anhydro Monosaccharides from TFA Hydrolysis of Brans[a]

no.	source	Rh	Ar	Xy	Ma	Ga	Gl	total[b]
1	bran, sorghum, Feterita	tr	3.8	3.1	0.3	0.6	26	33.8 (7.8)
2	bran, sorghum, Tam 680	0.1	6.8	5.4	0.3	0.7	25	38.3 (13.3)
3	bran, sorghum, Funk G766W	0.1	7.4	5.9	0.4	0.8	46	60.6 (14.6)
4	bran, corn, Staley CFJ3101A	0.2	12.7	22.3	0.1	3.2	3.7	42.2
5	bran, corn, Quaker	0.1	12.9	24.0	N	3.4	20	60.4 (40.4)
6	bran, rice, Calrose	tr	3.1	3.0	0.3	0.8	13	20.2 (7.2)
7	bran, rice, Kokuho	0.1	3.1	2.8	0.4	0.9	16	23.3 (7.3)
8	bran, wheat, soft white, AACC Ref R07-3691	N	8.1	13.5	0.3	1.0	28	50.9 (22.9)
9	bran, wheat, soft white, AACC 1980, certified as ref bran	N	7.6	14.0	0.2	1.0	25	47.8 (22.8)
10	bran, wheat, hard red spring, Waldron	N	10.0	15.0	0.1	1.2	13	39.3 (26.3)
11	bran, wheat, hard red spring, AACC STD 1980, certified as ref bran	N	9.3	16.4	0.4	1.1	16	43.2 (27.2)

[a] As percentage of dry sample. Key: Rh = rhamnose, Ar = arabinose, Xy = xylose, Ma = mannose, Ga = galactose, Gl = glucose; N = none detected; tr = detected but too small to quantitate. [b] Numbers in parentheses are totals excluding glucose.

hemicelluloses (Table III). Glucose values are mainly due to starch, except for soy beans which have no starch. There appears to be a species-related similarity in composition. The ratio Ar:Xy:Ma:Ga for the three *Phaseolus vulgaris* varieties, California Small White, Red Kidney, and Jacobs Cattle is 4.3:0.8:0.6:1, while for blackeye (*Vigna unguiculata*) it is 2.9:0.3:0.2:1, garbanzo (*Cicer arietinum*) 4.6:0.1:0.2:1, and soy (*Glycine max*) 0.5:0.2:0.1:1.

Combined non-glucose monomers are highest for the *Phaseolus* varieties at 7–8% and lowest for blackeye at 4%. The large amount of galactose for soy indicates the presence of larger amounts of galactose-containing hemicellulose in this bean compared to the others. After glucose, arabinose is the principal sugar found in all of the beans except soy.

Two preparations from soy beans that contain high concentrations of dietary fiber were analyzed (7, 8). Both samples contained sucrose and stachyose as determined by aqueous extraction and HPLC analysis (Olson et al., 1982). These sugars would be expected to contribute to the galactose and glucose values and indeed account for most of these sugars found in Nutrisoy fiber. Subtracting the amount of galactose corresponding to the stachyose present in Fitrate leaves 8–10% galactose that resulted from the hydrolysis of hemicellulose.

Brans. The bran samples examined produced predominantly arabinose, xylose, and glucose on hydrolysis (Table IV). Most of the glucose was considered to be from starch.

Sorghum brans (1–3) were obtained from experimental decorticating operations designed to clean or pearl the sorghum grains. The different values reflect the adherance of varying amounts of the seed coat to the endosperm. Decorticating sorghum means removing that portion of the grain that is mainly mesocarp. The mesocarp in the Funk variety is thicker than that in the other varieties and is known to contain starch, which may account for the high glucose value for this variety. The TFA hydrolysis procedure could be used to follow the extent of milling of samples by characterizing fractions in a definitive manner according to composition.

Corn bran from two different sources (4, 5) produced the same amount and distribution of monosaccharides excluding glucose. Both regular-milled and fine-milled samples of the A. E. Staley preparation gave the same results on hydrolysis. The larger amount of glucose in sample 5 is assumed to be from starch.

Calrose and Kokuho rice brans produced similar amounts of monosaccharides (6, 7). Non-glucose monosaccharides totaled 7.2% in both samples.

Wheat brans from two soft white wheats (8, 9) produced monosaccharide patterns that are similar to each other but different from brans from hard red wheats (10, 11). The latter contain significantly less glucose and slightly more arabinose and xylose than the soft whites. Sugars other than glucose amount to 23% for the soft whites and 27% for the hard reds. It is known that, in milling, soft white brans do not "clean" as well as hard reds, leaving starch in the bran fraction. This may account for the larger glucose values from the soft white brans. Differences between the non-glucose sugars are even smaller when glucose is assumed to be from starch and is subtracted from the totals and individual values are recalculated. Mean arabinose, xylose, and galactose values are then 11, 18.5, and 1.3%, respectively, for all of the wheat brans and amount to 31% of the starch-free solids. This compares well with the reported value of 28.5% hemicelluloses in wheat brans reported by Anderson and Clydesdale (1980). The free sugar content of these samples was found to be less than 0.2%.

Breads. More arabinose and xylose was produced from whole wheat bread on acid hydrolysis than from white bread (Table V). The arabinose to xylose ratio for white bread was 1.6 and for whole wheat bread it was 0.94. Total solids in the fresh white and whole wheat breads were 65.5 and 60.9%, respectively. The glucose from nonstarch noncellulose glucose-containing polysaccharides, deter-

Table V. Anhydro Monosaccharides from TFA Hydrolysis of Breads[a]

no.	source	Rh	Ar	Xy	Ma	Ga	Gl	total[b]
1	bread, white	N	0.9	0.6	0.3	tr	63	64.8 (1.8)
2	bread, whole wheat	N	2.0	2.1	0.3	0.4	52	56.8 (4.8)

[a] As percentage of dry sample. Key: Rh = rhamnose, Ar = arabinose, Xy = xylose, Ma = mannose, Ga = galactose, Gl = glucose; N = none detected; tr = detected but too small to quantitate. [b] Numbers in parentheses are totals excluding glucose.

Table VI. Production of Fecal Material in Human Study

			g feces/day[b] (dry-wt basis) for subjects					
	diet (test period, days)	N^a	14	2	3	4	5	6
I	basal diet (24)	5		26.2	8.7	25.6	18.4	20.5
II	white bread	3	21.9	22.6	18.8			
	wheat bread (24)	3				31.5	42.5	37.8
III	basal diet (12)	6	21.1	22.0	24.8	12.3	18.0	20.9
IV	white bread	3				16.0	13.7	16.6
	wheat bread (24)	3	42.9	51.0	47.6			

[a] Number of subjects on diet. [b] From final 6-day pooled dried sample from each respective test period. Geometric means followed by lower and upper 95% confidence limits for all diets: basal, $N = 11$, mean 19.0 (15.2, 23.8); white bread, $N = 6$, mean 18.0 (15.5, 20.9); whole wheat bread, $N = 6$, mean 41.7 (35.9, 48.5).

Table VII. Monosaccharides Produced by TFA Hydrolysis of Fecal Samples from Subjects on Basal, White Bread, and Whole Wheat Bread Diets[a] (Data Expressed as Milligrams of Anhydro Monosaccharide/Subject per Day)

	arabinose			xylose			mannose			galactose			glucose			total		
subject	B	W	WW	B	W	WW	B	W	WW	B	W	WW	B	W	WW	B	W	WW
2	14	120	3200	310	310	4270	110	150	280	340	260	510	1900	2300	1880	2674	3140	10140
3	4	70	2610	180	240	2860	33	53	81	73	72	280	510	470	680	800	905	6511
4	9	50	2330	480	270	1950	56	140	130	150	110	250	770	480	460	1465	1050	5120
5	8	50	3070	310	300	2580	80	47	120	100	50	290	580	460	570	1078	907	6630
6	12	100	1680	270	450	1460	79	78	120	140	130	230	730	570	480	1231	1328	3970
14	12	110	2630	350	430	2340	51	160	230	250	220	390	1200	2930	1880	1863	3850	7470
mean	9	78	2533	288	324	2438	64	93	146	141	120	312	781	858	819	1407	1549	6365
95% conf limit																		
lower	6	52	1683	218	216	1620	46	69	109	89	78	203	514	661	631	901	986	4049
upper	12	118	3811	381	488	3668	89	125	197	223	184	480	1187	1114	1064	2196	2435	10004

[a] Key: B = formula or basal diet; W = white bread diet; WW = whole wheat bread diet.

mined by hydrolyzing samples of breads that had been treated with amylase and amyloglucosidase to remove starch, was 1.47% in white bread and 1.71% in whole wheat bread.

Fecal Residue Polysaccharides from Breads Consumed by Humans. Breads used in this part of the investigation were described in the previous section. The sequence of feeding periods and production of fecal material by the test subjects on basal, white bread, and whole wheat bread diets are summarized in Table VI together with geometric means of pooled data and 95% confidence limits. Analysis of variance was run on log-transformed data in order to alleviate heterogeneity of variance problems and reduce the impact of some of the large subject differences. This analysis showed there was no interaction between the order in which the diets were fed and fecal output. Output from subjects on the whole wheat bread was more than twice that from basal and white bread diets, which were essentially the same. Results from each of the two diet periods for each diet are consistent with pooled results for all data. In addition, a comparison of fecal outputs from each subject on the three diets give the same results.

Analysis of fecal samples without prior acid hydrolysis showed there were no free monosaccharides present. The source of the monosaccharides produced by hydrolysis of fecal samples obtained from the subjects on the basal diet (Table VII) may be from the dietary α-cellulose, dextran starch, intestinal mucins, and/or bacterial residues. Hydrolysis of bacterial residues from pure cultures produced considerably smaller amounts of monosaccharides than hydrolysis of fecal samples from subjects on basal diets.

Results from the fecal hydrolyses were submitted to analysis of variance on log-transformed data for the aforementioned reasons and geometric means together with 95% confidence limits determined (Table VII). Although the absolute amounts were small, the significant increase in arabinose output from the white bread diet over the basal diet (78 vs 9 mg/day) was surprising in view of the fact that there was no significant difference in xylose output on these two diets (324 vs 288 mg/day). The source of this hydrolyzable xylose from the basal diet is not known. The large differences in arabinose (2533 vs 9 mg/day) and xylose (2438 vs 288 mg/day) in subjects on whole wheat bread vs the basal diet can be attributed to the large amounts of hemicelluloses present in the whole wheat bread. The differences noted between the means applied to each individual subject as well.

Data from the six subjects can be divided into two sets based on differences in recovery of monosaccharides. Fecal samples from subjects 2 and 14 contained more hydrolyzable glucose polymers than samples from subjects 3–6 for all three diets. For subjects 2 and 14 there was an increase in hydrolyzable glucose polymers from the white bread diet over both the basal and the whole wheat bread diet. These observations may be due to differences between the subjects gastrointestinal behavior and/or to differences in colonic microflora.

Comparison of Intake to Output. Hydrolyzable polysaccharides ingested were compared to those recovered in the feces. Amounts consumed were calculated from the results from the hydrolysis of the bread samples and the fact that the subjects consumed 1 lb of bread/day. From this and the net amount excreted on the bread diets over

the basal (bread free) diet, the amounts of anhydroarabinose, xylose, mannose, galactose, and glucose from subjects on the white bread diet were 2.5, 2.1, 3.2, −2.8, and 1.8% and from subjects on the whole wheat bread diet were 46.8, 37.4, 9.1, 16.4, and 0.8%, respectively. Total recovery of hemicelluloses was 2% from white bread and 28% from whole wheat bread diets.

More arabinose (46.8%) than xylose (37.4%) was recovered from subjects on the whole wheat bread, suggesting that xylose in the bread hemicelluloses was more rapidly fermented than arabinose. Particle size is known to have an effect on the digestibility and fermentation rate of wheat brans (Heller et al., 1980). The particle size of the bran particles in the whole wheat bread fed in this study was much smaller than that of the brans reported in Table I. This may have affected the fermentability as reflected in the arabinose to xylose ratios found in the fecal samples. In a previous study in which corn bran was fed, the arabinose to xylose ratio in the hydrolyzed feces showed that xylose was fermented more extensively than the arabinose (Olson et al., 1982), similar to the findings in this study with whole wheat bread.

In conclusion, direct TFA hydrolysis of foods and food components provides the monosaccharide composition of potentially fermentable hemicelluloses. Different hemicelluloses have different physical properties that effect physiological responses and fermentation in the colon, including rates of fermentation and volatile fatty acids produced. The amounts of these hemicelluloses that survive fermantation in the colon can be determined by the same direct hydrolysis method. Compared to results from a bread-free basal diet, none of the hemicelluloses from white bread were recovered in fecal material and one-fourth of those in whole wheat bread was recovered. Xylose and arabinose were the principal monosaccharides recovered but not in the same ratio as consumed.

ACKNOWLEDGMENT

We gratefully acknowledge gifts of rice bran from Dr. R. Sayre and sorghum bran from Dr. A. Shephard and help with statistical analysis of the data from Dr. B. Mackey.

Registry No. Cellulose, 9004-34-6; xylan, 9014-63-5; hemicellulose, 9034-32-6; trifluoroacetic acid, 76-05-1.

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Received for review April 13, 1987. Revised manuscript received November 30, 1987. Accepted December 10, 1987. Portions of this paper were presented in programs of the Division of Agricultural and Food Chemistry at the 182nd National Meeting of the American Chemical Society, New York, NY, Aug 1982, and the 190th National Meeting of the American Chemical Society, Chicago, IL, Sept 1985. Reference to a company and/or product named by the U.S. Department of Agriculture is only for purposes of information and does not imply approval or recommendation of the product to the exclusion of others that may also be suitable.