Effects of Rat Digestion upon Native, Enzymically or Chemically Modified Wheat Brans and Native Oat Bran

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ABSTRACT

Utilization of native or modified cereal brans by the rat was investigated. In a first experiment, during a four-week period, weanling rats were fed one of six diets: control, oat bran, or native, air-classified, enzymically destarched, or chemically delignified wheat bran. Excretion variables (rate, transit time, feces moisture, stool weight, and defecation frequency) were measured. Dietary fiber of the collected feces was analyzed. In a second experiment, adult rats were fed for four days with a control diet or with isofibrous diets containing enzymically destarched or chemically delignified wheat bran or hemicellulose A extracted from the same wheat bran. Excretion variables and apparent digestibility of the dietary fiber components were measured. Wet feces excretion rate, feces moisture, stool weight, and defecation frequency were positively correlated with the dietary fiber content of the diet, whereas transit time was negatively correlated. Cellulose apparent digestibility was around 15% and lignin digestibility about 0%, whereas digestibility of hemicellulose was as high as 50% except for that of hemicellulose A (95%). Differences in degradation of cell-wall polysaccharides were studied; water-soluble hexosans of oat bran and of native and air-classified wheat brans were easily digested, whereas for all bran samples studied, hexosan and pentosan moieties of insoluble hemicelluloses were degraded to the same extent. Of the monomeric sugars, β-glucans were the most degradable, followed by xylan and then arabinan. An overall correlation matrix was established for nutritional, biochemical, and physical data.

Numerous reports (Beyer and Flynn 1978, Cummings et al 1978, Dintzis et al 1979, Heaton and Pomare 1974, Nomani et al 1979, Southgate et al 1976, Walters et al 1975) have been made on research with men and monogastric animals on the nutritional and physiological effects of cereal brans and of derived "fiber concentrates" obtained by chemical treatments. Other authors (McConnel et al 1974, Rasper 1979a) measured physical properties of brans or corresponding fiber fractions isolated chemically or enzymically and related these properties to biochemical data. Nevertheless, few studies have been conducted on interrelationships between nutritional, biochemical properties and physical data of fibers. The purpose of the present study was to correlate growth, transit time, and fiber digestibility in the rat with biochemical composition and physical properties of fiber sources. In order to change ratios of individual components of dietary fiber, we included in the diets either native brans (wheat and oat) or wheat brans modified physically (air-classification), enzymically (destarching), or chemically (delignification).

MATERIALS AND METHODS

Materials

Native and air-classified wheat brans (*Triticum vulgare*), the latter being prepared from the native one, were ground to pass a 0.5-mm screen. Enzymically destarched bran, holocellulose (destarched and delignified bran), and hemicellulose A were prepared from the native wheat bran as described in Fig. 1 (Brillouet and Mercier 1981). Hemicellulose A, commonly defined as the polysaccharide precipitated by acidification to pH 4.8 of the alkaline extract of a plant material (O'Dwyer 1926), was mainly a xylan in our case (Brillouet and Mercier 1981). Defatting and ammonium oxalate extraction were, however, omitted from the procedure. Isolated material was dehydrated by washing with ethanol, acetone, and ether and was dried under infrared lamps. Oat bran was obtained by milling dehulled oat kernels (Station Amélioration Plantes, Le Rheu, INRA, France) in a laboratory mill (Chopin, Paris, France) and processing the resultant bran in a brush (Chopin, Paris, France) to remove most of the adhering endosperm. Oat bran was reduced in size to pass through a 0.5-mm screen.

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Experiment 1: Effect of Native and Modified Brans on Excretion Variables

Seventy-two Wistar albino male weanling rats (three weeks old) weighing approximately 40 g were divided into six groups of 12 each and caged individually in randomly arranged stainless steel cages at 20°C. The rats were fed for two days with laboratory stock diet, then for four weeks with test diets (Table I). Water and experimental diets were provided ad libitum. At the end of this period, four rats of each group were placed in individual metabolism cages. Transit time was determined twice with chromium oxide within 24-hr periods according to Gohl and Gohl (1977), from which defecation frequency was calculated. Weight and dry matter of stools were also measured.

Experiment 2: Apparent Digestibilities of the Individual Components of Dietary Fiber

Twenty-four Wistar albino male weanling rats (seven weeks old) weighing approximately 160 g were divided into six groups of four

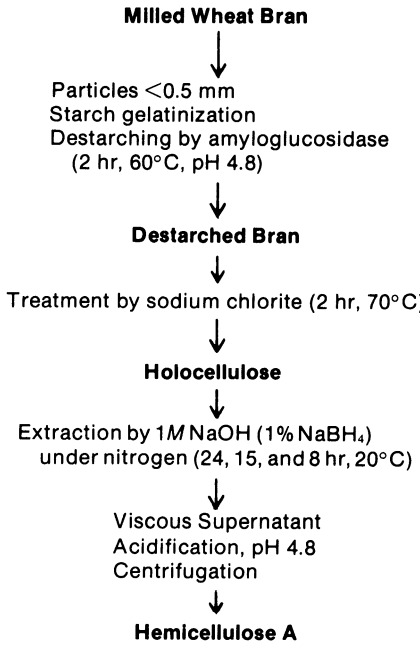

Fig. 1. Fractionation scheme for preparation of destarched wheat bran, holocellulose, and hemicellulose A from native wheat bran (adapted from Brillouet and Mercier 1981).

each and placed in individual metabolism cages at 20°C. Test diets (Table I) and water were provided ad libitum for 11 days. Feces and urines were collected, and feed intake was measured during a four-day period. Transit time, defecation frequency, and weight and dry matter of stools were measured as described.

Analytical Procedures

Moisture was determined by drying at 130°C for 2 hr. All results, if not specified, were given on a moisture-free basis. Nitrogen was determined by Kjeldahl procedure. The loss in weight due to exhaustive Soxhlet extraction with diethyl ether was taken as fat. Ash was determined by incinerating at 550°C overnight. Sugars were determined in 80% ethanolic extract by the anthrone method (using glucose as standard). Starch was measured enzymically by the amyloglucosidase method (Thivend et al 1972). Neutral-detergent and acid-detergent fibers, cellulose, and lignin of diets and feces from experiment 2 were also determined by Van Soest methods (Van Soest 1963a, 1963b; Van Soest and Wine 1968). Fractionation and determination of the components of dietary fiber in all bran samples and feces were carried out according to a modification of Southgate's procedure (Southgate et al 1978). Starch was gelatinized by boiling the water suspension of the sample for 15 min and then hydrolyzed with amyloglucosidase (Merck, Germany) for 2 hr at 60°C (Thivend et al 1972); glucose and pentoses were determined in the hydrolysate. The destarched residue was suspended in 0.075*N* HCl and digested with pepsin (Calbiochem, La Jolla, CA) for 48 hr at 40°C (50 mg of pepsin per 1 g of sample). The residue was washed thoroughly with water and dried through ethanol and acetone. Further fractionation and analytical determination of the monomeric components (hexoses and pentoses) were performed as described (Southgate et al 1978). For analysis of sugars by gas-liquid chromatography (GLC), all

TABLE I
Composition and Proximate Analysis (%) of Test Diets

	Fiber Source and Diet Designation									
	Experiment 1						Experiment 2			
			Wheat Bran					Wheat Bran		
Ingredient	Control (A)	Oat Bran (B)	Native (C)	Air-Classified (D)	Destarched (E)	Holocellulose (F)	Control (G)	Destarched (H)	Holocellulose (I)	Hemicellulose (J)
Composition										
Corn starch	71.5	63.2	62.9	62.7	61.9	63.3	72.0	62.0	62.0	62.0
Casein	18.0	16.5	16.8	17.0	17.8	16.4	18.0	16.7	17.7	17.8
Peanut oil	5.0	5.0	5.0	5.0	5.0	5.0	4.7	4.7	4.7	4.7
Mineral mix[a]	4.5	4.5	4.5	4.5	4.5	4.5	4.2	4.2	4.2	4.2
Vitamin mix[b]	1.0	1.0	1.0	1.0	1.0	1.0	0.9	0.9	0.9	0.9
Fiber source	0.0	10.0	10.0	10.0	10.0	10.0	0.0	11.3[c]	10.3[c]	10.2[c]
Proximate Analysis										
Starch	70.4	66.8	63.5	61.9	61.5	60.7	71.0	61.0	61.0	61.0
Crude protein	18.3	18.4	17.8	18.1	18.4	18.3	17.7	17.5	17.2	17.8
Fat	5.0	5.8	5.7	5.5	5.3	5.1	4.7	5.0	4.8	4.7
Dietary fiber[d]	2.2	3.4	7.0	9.0	10.3	11.2	2.1	11.4	11.3	11.8

[a]Composition according to AOAC methods (1965).
[b]Composition according to AOAC methods (1965) but dextrose replaced by cellulose "CEPO" grade SS200, containing 20% associated xylan (Durieux, Paris, France).
[c]Fiber sources added at different proportions to make isofibrous diets.
[d]Calculated from proximate analysis of each ingredient by Southgate fractionation procedure (Southgate et al 1978).

TABLE II
Total Analysis (%) and Physical Properties of Fiber Sources Included in Diets

	Fiber Source and Diet Designation					
		Wheat Bran				
Constituent	Oat Bran (B)	Native (C)	Air-Classified (D)	Destarched (E, H)	Holocellulose (F, I)	Hemicellulose A[a] (J)
Moisture	10.5	12.8	12.4	12.0	11.9	2.9
Fat	8.8	6.6	5.4	2.9	1.3	0
Ash	3.8	7.0	5.3	2.0	8.0	0
Protein (N × 5.7)	13.8	14.0	10.5	9.6	1.7	2.2
Sugars	2.5	6.0	5.8	1.1	0.1	0
Starch	51.9	13.7	2.4	0.3	0.2	0
Hemicellulose[b]	15.0	38.0	52.2	57.9	68.9	94.9
Cellulose[b]	1.5	7.6	11.5	16.4	17.7	0
Lignin[b]	1.4	4.2	6.9	9.2	4.0	n.d.[c]
Total recovered	98.7	97.1	100.0	99.4	95.9	97.1
Yield (% native wheat bran)	...	100.0	41.0	56.2	34.5	5.4
Bulk volume (ml/g)	2.4	3.2	3.0	3.6	7.2	n.d.[c]
Swelling (mg/g)	1.2	2.2	4.0	3.4	3.6	n.d.[c]
Water retention (g/g)	1.7	3.5	4.8	6.1	8.0	n.d.[c]

[a]Content calculated from monosaccharides composition determined by gas liquid chromatography (Brillouet and Mercier 1981).
[b]Determined according to modified Southgate procedure (Southgate et al 1978).
[c]Not determined.

test fiber sources, basal cellulose, and feces were submitted to Saeman hydrolysis (Saeman et al 1954): 72% H_2SO_4 for 2 hr at 20°C, dilution to 2*N*, and heating for 2.5 hr at 100°C. The hydrolysates were neutralized with barium hydroxide, and neutral sugars were converted to their alditol acetates (Sawardeker et al 1965) for analysis. GLC was performed on 3% SP2340 (Supelco, Bellefonte, PA). Monosaccharides determined by Southgate's procedure and GLC analysis are reported in their anhydro (polymeric) form. Because of a relatively low dietary fiber content and high starch content in the diets, Southgate's fractionation procedure was not found suitable for their dietary fiber analysis. The distribution of the dietary fiber components in the diets was calculated from the composition of the individual dietary fiber supplements.

Physical Properties

Bulk volume, swelling, and water retention capacity were measured using techniques described by McConnel et al (1974) and Rasper (1979b).

Statistical Procedures

Means, standard errors, Student's *t*-test, analyses of variance, and regression were calculated according to standard procedures (Snedecor and Cochran 1968).

RESULTS AND DISCUSSION

Analysis of Brans

Chemical analysis of all materials used as a source of dietary fiber in the rat diets is given in Table II. A more detailed analysis of the dietary fiber fractions of these materials, including data on percent distribution of the individual components, is presented in Table III. The composition of native wheat bran was very similar to previous reported data (Fraser and Holmes 1959, Lee and Stenvert 1973). The dietary fiber content ranged from 13.1% (oat bran) to 90.6% (holocellulose). Because of this great variation, percent distribution data served as an appropriate indicator of the extent to which the individual components were affected by the applied treatments. Air classification of the native bran increased substantially its total dietary fiber fraction by removing a great portion of starch, but at the same time it resulted in a moderate reduction of the hemicellulose fraction, mainly from a partial removal of some of the hexosan component. An even more pronounced reduction of the hemicellulose fraction was observed after the amylolytic treatment of native bran. After this treatment, the hexosan fraction of hemicellulose accounted for 7.7%, an almost 50% reduction from the level in native bran. The presence of hot water soluble hemicellulosic material, mainly glucosan, has already been

TABLE III
Composition of Dietary Fiber Sources and Percent Distribution of the Individual Components

	Fiber Source and Diet Designation									
			Wheat Bran							
Constituent	Oat Bran (B)		Native (C)		Air-Classified (D)		Destarched (E, H)		Holocellulose (F, I)		Hemicellulose A[a] (J)	
Hemicelluloses												
Hexoses	2.9[b]	(21.3)[c]	7.0	(14.1)	8.0	(11.3)	6.5	(7.7)	8.1	(8.9)	16.2	(17.1)
Pentoses	7.0	(51.8)	30.1	(60.5)	43.1	(61.1)	50.2	(60.2)	59.6	(65.8)	77.3	(81.5)
Uronic acids	0.7	(5.0)	0.9	(1.7)	1.2	(1.6)	1.2	(1.5)	1.3	(1.4)	1.4	(1.4)
Total	10.6	(78.2)	38.0	(76.3)	52.2	(73.9)	57.9	(69.4)	68.9	(76.1)	94.9	(100.0)
Cellulose												
Hexoses	1.0	(5.6)	5.9	(11.9)	9.3	(13.2)	13.4	(16.0)	14.7	(16.2)	0.0	(0.0)
Pentoses	0.3	(2.3)	1.0	(2.0)	1.6	(2.3)	2.2	(2.6)	2.5	(2.7)	0.0	(0.0)
Uronic acids	0.2	(1.9)	0.7	(1.5)	0.5	(0.8)	0.8	(1.0)	0.5	(0.6)	0.0	(0.0)
Total	1.5	(11.2)	7.6	(15.3)	11.5	(16.3)	16.4	(19.6)	17.7	(19.5)	0.0	(0.0)
Lignin	1.5	(10.7)	4.2	(8.4)	6.9	(9.8)	9.1	(11.0)	4.0	(4.4)	n.d.[d]	(n.d.[d])
Total dietary fiber	13.1	(100.0)	49.8	(100.0)	70.6	(100.0)	83.5	(100.0)	90.6	(100.0)	94.9	(100.0)

[a]Composition determined by gas liquid chromatography and carbazol method (Brillouet and Mercier 1981).
[b]Percent of dry matter.
[c]Percent of total dietary fiber given in parentheses.
[d]Not determined.

TABLE IV
Effect of Test Diets on Excretion Variables[a]

Fiber Source	Diet	Excretion Rate[b] (g/hr)	Transit Time[c] (hr)	Feces Moisture[c,d] (%)	Stools Weight[e] (g)	Defecation Frequency[f] (number of stools/hr)
Control	A	0.045 g ± 0.003	12.8 h ± 1.2	44.4 g ± 2.0	0.08	0.5
Oat bran	B	0.110 h ± 0.004	13.3 h ± 0.9	48.4 g ± 0.5	0.12	0.8
Wheat bran						
Native	C	0.106 h ± 0.003	11.4 gh ± 1.5	46.2 g ± 2.1	0.13	0.7
Air-classified	D	0.113 h ± 0.002	10.4 gh ± 0.8	46.6 g ± 1.2	0.12	0.9
Destarched	E	0.144 i ± 0.004	10.3 gh ± 1.2	48.2 g ± 1.8	0.13	1.0
Holocellulose	F	0.167 j ± 0.003	9.1 g ± 1.0	50.8 g ± 1.1	0.12	1.2
Control	G	0.033 ± 0.010	15.9 h ± 2.0	32.4 g ± 2.1	0.05	0.5
Wheat bran						
Destarched	H	0.129 h ± 0.003	12.4 h ± 1.4	47.6 g ± 0.9	0.10	1.0
Holocellulose	I	0.135 hi ± 0.004	12.2 h ± 0.9	50.2 g ± 2.1	0.10	1.0

[a]Means sharing a common letter do not differ significantly ($P > 0.05$).
[b]Slope of the regression line between time and total quantity of wet feces excreted, ± SE.
[c]Mean ± SEM.
[d]Percent of water in wet feces.
[e]Weight of all wet feces divided by number of stools.
[f]Number of stools divided by total time of collection.

observed in wheat bran (Brillouet and Mercier 1981, Theander and Aman 1979). Destarching consequently provided a material without hot water soluble hemicellulosic fractions, mainly hexosans, which allowed us to point out the particular behavior of these polysaccharides as compared to that of the whole wheat bran. Delignification by oxidation with sodium chlorite resulted in a product with approximately two thirds of the original lignin removed. Oat bran dietary fiber was characterized by a relatively high hexosan level in the hemicellulose fraction, which might be due to the presence of noncellulosic β-glucans (Montgomery and Smith 1956).

Excretion Variables

Data from experiments 1 and 2 are presented in Table IV. In each transit time measurement, a highly significant linear relationship ($P < 0.01$) was found between the weight of wet feces excreted from the beginning of the transit time experiment (feces cumulated for all rats of each diet trial) and the time of collection. Therefore, the excretion rate (grams of feces per hour) could be expressed by the slope of the regression line. Excretion rate, defecation frequency, moisture, and mean weight of stools increased when transit time decreased ($P < 0.05$). Increasing the dietary fiber content of the diet resulted in an increased excretion rate; this is a well-known, commonly observed phenomenon (Beyer and Flynn 1978). However, diet B (oat bran) induced a higher rate than the other diets, given its dietary fiber content and composition. Consequently oat bran acted differently than native and modified wheat brans did.

TABLE V
Effect of Diets Containing Dietary Fiber on Apparent Digestibility and Balance Variables (%)

	Fiber Source and Diet Designation			
		Destarched		
Apparent Digestibility of	Control (G)	Bran (H)	Holocellulose (I)	Hemicellulose A (J)
Dry matter[a,b]	94.6 e ± 1.8	87.2 f ± 1.1	87.6 f ± 0.9	94.5 e ± 1.4
Protein[c]	90.6	86.6	86.9	92.1
Cellulose[c,d]	36.8	17.1	15.4	12.6
Hemicelluloses[c,d]	...	47.5	51.1	96.3
Lignin[c,d]	−10.9	16.9	−11.4	5.5
Apparent net protein utilization[c]	45.9	41.4	38.6	19.7

[a] Results obtained by separate collection of feces from six rats during four days (mean ± SEM).
[b] Means sharing a common letter do not differ significantly ($P > 0.05$).
[c] Results obtained by gathering feces of six rats (one analysis for each diet).
[d] Apparent digestibilities of cellulose, hemicelluloses, and lignin were calculated from analysis according to Van Soest methods (Van Soest 1963a, 1963b; Van Soest and Wine 1968).

Apparent Digestibility

The amounts of food intake during feces collection in experiment 2 (Table V) were statistically different between diets G, H, and I (mean = 45.5 ± 3.2 g per rat for the four-day collection period) and diet J (mean = 34.7 ± 1.6 g). This is possibly due to the low palatability of diet J induced by traces of *n*-octanol, which was used as an antifoaming agent during purification of hemicellulose A. Large differences in digestibility could not be completely explained by these variations of intake, however. Dry matter digestibility of diets H and I (destarched bran and holocellulose) differed significantly from diets G and J (control and hemicellulose A). Because diets H, G, and J were isofibrous, the diet containing hemicellulose A was as digestible as was the control diet.

Protein digestibility was correlated with dry matter digestibility ($P < 0.01$). The apparent net protein utilization of diet J protein (hemicellulose A) was very low, for unknown reasons.

Apparent digestibilities of cellulose of diets H and I (destarched bran and holocellulose) were of the same magnitude as those observed by Keys et al (1970) with rats fed ad libitum with 20% orchardgrass hay diet and by Garrison et al (1978) with rats eating a diet in which bagasse was included at the 5% acid-detergent fiber level. Similar data were obtained with men supplied with wheat bran (Dintzis et al 1979). Surprisingly, cellulose digestibility was not improved after partial removal of original lignin. Comparison of cellulose digestibility of diet G, containing no hemicellulose and diet J (10% hemicellulose) shows that cellulose digestibility was lowered if isolated hemicellulose was added. Digestibility of hemicelluloses was almost unchanged after delignification, contrary to the findings of Fahey (1979), who observed with guinea pigs an increased digestibility of wheat straw hemicelluloses after delignification. In our study, hemicellulose A purified from wheat bran was almost completely digested, showing that the physiological properties of an isolated polysaccharide cannot be compared to those in complex cell-wall structures (Fahey 1979, Keys et al 1970).

The high apparent digestibility of hemicellulose A might explain the low cellulose digestibility in diet J; gut microflora seemed to use preferentially the easiest degradable substrate. Lignin digestibility results have to be considered very cautiously because of the insufficient accuracy of the analytical procedure. We also suspected that a relatively high protein content in the feces may create conditions for the formation of an artifact lignin (Streeter 1969). As usually observed by several authors (Gordon 1978), lignin apparent digestibility was around zero.

Comparison of the Extent of Degradation of Dietary Fiber Polysaccharides

Southgate's fractionation (Southgate et al 1978) provided hemicelluloses and cellulose fractions that were essentially composed of hexoses and pentoses. In order to test whether one class of sugars was preferentially degraded, hexoses-pentoses ratios of hemicelluloses or cellulose of diets and corresponding feces were

TABLE VI
Comparison of Pentoses and Hexoses Composition[a] of Diets and Feces

		In Diet				In Feces				Hexoses-Pentoses Ratio			
		Cellulose		Hemicelluloses		Cellulose		Hemicelluloses		Cellulose		Hemicelluloses	
Fiber Source	Diet	Hexoses	Pentoses	Hexoses	Pentoses	Hexoses	Pentoses	Hexoses	Pentoses	Diet	Feces	Diet	Feces
Control	A	0.61	0.15	0.60	0.52	2.66	1.00	1.86	1.47	4.1	2.7	1.2	1.3
Oat bran	B	0.72	0.25	0.89	1.23	11.32	1.33	5.90	26.63	2.9	8.5	0.7	0.2
Wheat bran													
Native	C	1.20	0.25	1.29	3.50	8.40	1.55	4.88	20.76	4.8	5.4	0.4	0.2
Air-classified	D	1.53	0.31	1.39	4.78	8.71	1.11	5.43	28.42	4.9	7.8	0.3	0.2
Destarched	E	1.94	0.36	1.24	5.49	11.41	1.34	6.11	30.29	5.4	8.5	0.2	0.2
Holocellulose	F	2.06	0.40	1.40	6.42	13.47	1.58	6.82	30.65	5.2	8.5	0.2	0.2
Control	G	0.55	0.14	0.60	0.52	2.91	0.78	0.97	0.82	3.9	3.7	1.2	1.2
Wheat bran													
Destarched	H	2.06	0.37	1.33	6.19	11.83	1.37	5.09	24.93	5.6	8.6	0.2	0.2
Holocellulose	I	2.06	0.39	1.43	6.66	15.15	1.24	4.91	23.29	5.3	12.2	0.2	0.2

[a] All results expressed as percent of dry matter.

compared (Table VI). Ratios for hemicelluloses in diets E, F, H, and I and related feces were almost identical, indicating that pentosan and hexosan moieties of the water-insoluble hemicelluloses were degraded at the same rate. The decrease of ratios for hemicelluloses in diets B–D (containing hot water soluble hexosans) after transit through the gut showed that total hemicellulosic hexosans were degraded to a greater extent than pentosans, as earlier observed by Southgate on men fed wheat bran (Southgate et al 1976). Ratios for cellulose were slightly higher for feces than for diets, indicating that pentosans determined in Southgate's cellulose were more digested than hexosans were. Nevertheless, because two types of cellulose were added in the diets (basal and bran cellulose) and because the biochemical and nutritional meaning of "cellulosic pentosans" was questionable, no hypothesis could be developed to explain observed differences.

In the same way, arabinan-xylan and β-glucans-xylans ratios were compared in diets and feces (Table VII, Fig. 2). Arabinan-xylan ratios were well correlated between diets and feces. The relationship was

$$\frac{\text{arabinan (feces)}}{\text{xylan (feces)}} = 1.32\left(\frac{\text{arabinan (diet)}}{\text{xylan (diet)}}\right) - 0.07$$

$$(r = 0.982,\ P < 0.01)$$

Slope was different from unity and intercept not different from zero ($P < 0.05$), indicating that arabinan was less degraded than xylan and that gut microflora did not produce arabinanlike material. Statistical treatment of β-glucans gave the following equation:

$$\frac{\beta\text{-glucans (feces)}}{\text{xylan (feces)}} = 0.65\left(\frac{\beta\text{-glucans (diet)}}{\text{xylan (diet)}}\right) + 0.54$$

$$(r = 0.999,\ P < 0.01)$$

β-Glucans seemed to be produced by microorganisms; diet without this component induced feces with a ratio different from zero ($P < 0.01$). Moreover the slope indicated that β-glucans were more degradable than xylan ($P < 0.01$). Therefore the concentration of these carbohydrates in the feces was the outcome of two opposite actions: simultaneous degradation and synthesis by microorganisms. The overall order of decreasing degradability was: (hemicellulosic plus cellulosic) β-glucans, xylan, and arabinan. Comparison of this result with the data of Table VI suggested that hemicelluloses of native wheat and oat brans are constituted of at least two classes of polysaccharides: a fraction mainly composed of water-soluble β-glucans (Brillouet and Mercier 1981, Montgomery and Smith 1956), which is easily digestible, and a second insoluble one, essentially composed of arabinoxylans associated with glucans moieties (Adams 1955, Brillouet and Mercier 1981), less degradable and having a hexose-pentose ratio of about 0.2.

Interrelationships Between Nutritional, Biochemical, and Physical Data

For each set of data (compositions of the diets, physical properties of the diets, compositions of the feces, excretion variables) except for those of diet J, we established a correlation matrix from which we chose the most significant variables according to certain criteria: correlation with other variables at least at $P < 0.01$ or correlation ($P < 0.01$) with no other data. An overall correlation matrix (Table VIII) was established with these selected data.

Dietary fiber content (positively correlated with hemicelluloses and cellulose) and water retention of the diets were correlated, as observed by McConnel et al (1974); however, negative correlation was found between water retention and crude cellulose of cereal fiber samples by Rasper (1979a). These contradictory results may be explained by the negative correlations between hemicelluloses and cellulose in the cereal fiber samples studied by Rasper (1979a)

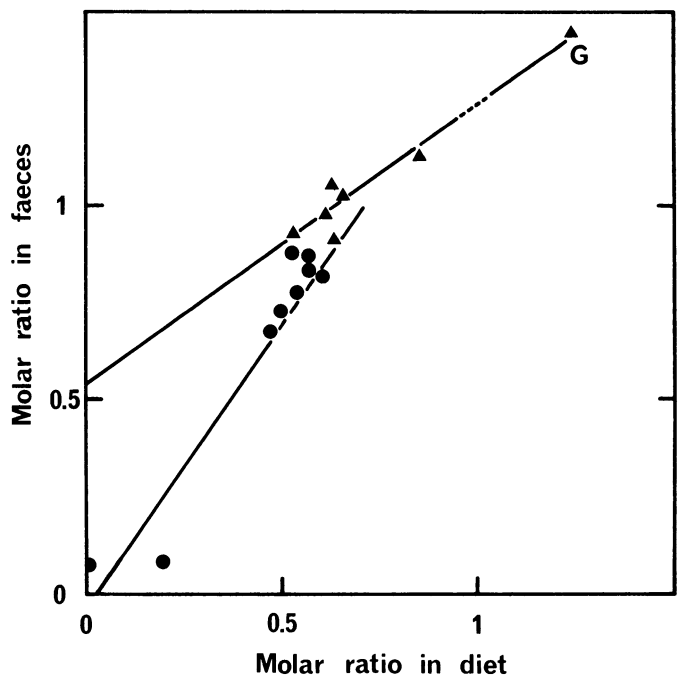

Fig. 2. Arabinan-xylan (●-●) and β-glucans-xylan (▲-▲) molar ratios in the feces as a function of the corresponding ratios in the diets.

TABLE VII
Comparison of Arabinan, Xylan, and β-Glucans Contents[a] in Diets[b] and Feces

		In Diet			In Feces			Ratios: Arabinan/Xylan		Ratios: β-Glucans/Xylan	
Fiber Source	Diet	Arabinan	Xylan	β-Glucans	Arabinan	Xylan	β-Glucans	Diet	Feces	Diet	Feces
Control	A	0.0	0.6	3.2	n.d.[c]	15.8	n.d.	0.00	n.d.	5.33	n.d.
Oat bran	B	1.7	3.1	n.d.	74.5	91.5	99.0	0.54	0.81	n.d.	1.08
Wheat bran											
Native	C	5.8	11.6	10.4	56.9	81.0	90.0	0.50	0.70	0.90	1.11
Air-classified	D	8.9	19.5	10.1	69.8	109.1	101.0	0.45	0.64	0.52	0.92
Destarched	E	11.7	23.1	14.6	73.3	98.6	102.0	0.51	0.75	0.63	1.03
Holocellulose	F	12.0	20.7	12.8	103.2	134.9	122.5	0.58	0.77	0.62	0.91
Control	G	0.0	0.6	2.8	0.6	9.4	36.0	0.00	0.07	4.67	3.83
Wheat bran											
Destarched	H	13.3	26.4	16.1	93.9	112.0	119.0	0.50	0.84	0.61	1.06
Holocellulose	I	11.5	21.4	12.8	82.1	103.8	101.0	0.54	0.79	0.60	0.97

[a] Expressed as millimoles of anhydrosugar per 100 g of dry matter.
[b] Diet contents calculated from fiber sources composition determined by gas-liquid chromatography and taking into account basal cellulose composition.
[c] Not determined.

TABLE VIII
Correlation Matrix for Biochemical, Physical, and Physiological Data from Experiments 1 and 2 (Diet J Excluded)

	Diet			Feces Content			
	Dietary Fiber Content	Water Retention[a]	Excretion Rate	Moisture	Dietary Fiber	Fat	Starch
Water retention, diet	0.866[b]						
Excretion rate	0.875[b]	0.882[b]					
Feces contents							
Moisture	0.739[c]	0.783[b]	0.892[b]				
Dietary fiber	0.836[b]	0.748[c]	0.933[b]	0.850[b]			
Fat	−0.682[c]	−0.617	−0.527	−0.228	−0.559		
Starch	−0.242	−0.103	−0.207	−0.028	−0.365	0.315	
Lignin	0.435	−0.020	0.232	0.105	0.461	0.276	−0.614

[a] Water retention of the diet calculated from water retention of fiber sources (Table II).
[b] $P < 0.01$.
[c] $P < 0.05$.

and the positive one in our cases. Finally, hemicelluloses of the fiber sources seemed to be the major factor responsible for water retention. The same interpretations could be made to explain the positive correlation between dietary fiber content and moisture of feces. Excretion rate was obviously correlated with ingested dietary fiber. Starch and lignin content of feces were not correlated with other data; however, lignin in diets and feces were correlated ($r = 0.841$, $P < 0.01$). Lignin has no effect on all measured physiological variables and consequently acted as an inert undigestible material. Moreover, starch content of feces, being very low, seemed to have no analytical meaning. As previously observed by Keim and Kies (1979), fat content of feces was negatively correlated with dietary fiber content of the diet.

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