NOTE

Fecal Bulking Effect of Whole Grain Flour from Selected Grains[1]

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ABSTRACT

In a four-week study, young rats were fed diets containing whole grain flour from wheat, oats, rye, or barley. At the 50% level used, these diets provided a total of 1.6, 3.0, 3.5, and 10.4 g of soluble fiber (SF) and 17.0, 10.6, 17.5, and 45.1 g of total dietary fiber (TDF), respectively. Two groups of rats were fed SF-free diets (cellulose-based) that provided 10.5 or 44.9 g of TDF. Fecal dry weights in the grain-fed rats averaged 22.6 (wheat-fed), 15.2 (oat-fed), 20.9 (rye-fed), or 44.9 (barley-fed) g for the four-week period. These weights were poorly correlated with SF intakes but highly correlated with TDF ($r = 0.97$) and insoluble fiber ($r = 1.00$). Fecal densities were significantly lower in rats fed cellulose- or wheat-based diets than in rats fed comparable (based on TDF intake) diets based on the other three grains.

A high fecal bulk, usually the consequence of a high fiber diet, is associated with a lower incidence of colon cancer (NCI 1985, Anderson 1986, Pilch 1987). Whole grain flours, because they contain more fiber than do the resultant refined flours, provide a greater fecal bulk than do refined flours.

The content of fiber in whole grain flours is not the only factor that determines their fecal bulking capacity. Other factors, such as particle size, water-holding capacity, the presence of resistant starch, and the amount of soluble fiber (SF) they contain may also affect fecal bulk (Nyman and Asp 1982, Nyman 1985, Cadden 1986, Nyman et al 1986, Ranhotra et al 1991).

SF is a significant component of total dietary fiber (TDF) in grains such as oats, barley, and rye. These grains are increasingly being incorporated into foods as a source of SF to lower elevated blood cholesterol, which is a risk factor in heart disease (Jenkins et al 1979). They undoubtedly also provide fecal bulk, but their relative capacity to do so is not well understood. The present study was undertaken to assess this capacity. Wheat, which is low in SF, and cellulose, which contains no SF, were used as control materials. Rats were used as the test model; they have been shown to respond in a manner similar to humans in this type of study (Nyman and Asp 1982, Nyman 1985, Nyman et al 1986).

MATERIALS AND METHODS

Test Samples

All grains were ground (Wiley mill, model 4, Arthur H. Thomas Co., Philadelphia, PA) to pass through a 0.84-mm screen. The cellulose used as a control fiber source was obtained from a commercial source. Table I provides information on the composition of these samples.

Diets

Test samples were included in the diet at the 50% level (Table II). The two control (cellulose-based) diets represented the lower (4.6%) and the upper (19.6%) levels of TDF as encountered in the four grain-based diets. All diets were complete in nutrients required by rats (NRC 1987).

Animals

Six groups of male weanling rats (10 per group) of Sprague-Dawley strain (Harlan-Sprague-Dawley, Indianapolis, IN) were housed individually in suspended mesh-bottom stainless steel cages in a controlled environment. Sliding trays for fecal collection were provided under each cage. Each rat was allowed to consume an adequate, but the same (pair-fed), amount of total diet over the four-week test period; deionized water was offered ad libitum. Records of body weight were kept.

Fecal Collection

Feces were collected quantitatively (separately for each rat) throughout the four-week period, pooled, air-dried, and weighed, and their volumes were determined.

Analyses

The standard AACC methods (AACC 1983) were used to analyze test samples for protein (Kjeldahl), fat (acid hydrolysis), moisture, and ash. Fiber (TDF and SF) was determined by the enzymatic-gravimetric method of Prosky et al (1988). Fecal volume was determined in a long-stemmed, graduated cylinder, using fine sand as the embedding material. Density was calculated by dividing the fecal dry weights by volume.

Statistical Analyses

Mean comparisons were made with Duncan's multiple-range test using the Statistical Analysis System (SAS 1982).

RESULTS AND DISCUSSION

Diet and Fiber Intakes

To eliminate the effect of ad libitum feeding on fecal bulk, all groups of rats were allowed to consume identical amounts of diets (Table III). These diets, however, differed in TDF and SF contents (Table II) and, as such, the intakes of TDF and SF varied greatly among groups of rats.

Body Weight Gains

All diets contained the same level of fat and protein (Table II). However, they differed in caloric density because the fiber levels differed; diets low in TDF and containing some SF promoted higher body weight gains in rats than diets devoid of SF or containing high levels of TDF.

Fecal Weight

Although a low fecal weight (or bulk) does not necessarily promote cancer, a high weight may protect against colon cancer (NCI 1985). Fecal weight is invariably higher in rats on fiber-containing diets than in those on fiber-free diets (Schneeman 1987, Ranhotra et al 1988).

However, fiber-containing diets may differ in their potential to increase fecal weights even when they contain identical amounts of TDF. Such seems to be the case for sets of diets A and E and diets B and F. Diets A and B, in which cellulose was the fiber source, promoted significantly ($P < 0.05$) higher fecal dry weights than did the corresponding diets (diet E, oat-based, and diet F, barley-based). This may result from SF in oats and barley

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TABLE I
Composition (%) of Test Samples

Sample	Moisture	Protein (N × 5.7)	Ash	Fat	Total Dietary Fiber	Soluble Fiber[a]	Carbohydrates
Cellulose[b]	3.8	...	0.2	0.2	95.8	...	...
Whole grain flours							
Wheat	10.9	16.7	2.1	3.2	14.8	1.4	52.3
Rye	11.2	10.5	1.6	2.6	15.2	3.0	58.9
Oat	9.8	16.3	2.0	7.4	9.1	2.5	55.4
Barley	8.8	15.8	2.3	7.8	39.1	8.9	26.2

[a] Values were not used in calculating carbohydrate values.
[b] Alphacel (ICN Biochemicals, Cleveland, OH).

TABLE II
Test Diets of Rats

	Diet					
	A	B	C	D	E	F
Ingredients, %						
Cellulose	4.8	20.4	...	...	...	...
Wheat	...	...	50	...	...	...
Rye	...	...	...	50	...	...
Oat	...	...	...	...	50	...
Barley	...	...	...	...	...	50
Soybean oil	5.0	5.0	3.4	3.7	1.3	1.1
Gluten	15.1	15.1	3.2	7.6	3.5	3.9
Corn starch	67.2	51.6	35.5	30.8	37.3	37.1
Others[a]	7.9	7.9	7.9	7.9	7.9	7.9
Composition, %						
Total fiber	4.6	19.6	7.4	7.6	4.6	19.6
Soluble fiber	...	...	0.7	1.5	1.3	4.5
Total fat	5.0	5.0	5.0	5.0	5.0	5.0
Total protein	12.0	12.0	12.0	12.0	12.0	12.0

[a] Included (%): vitamin mix (1), mineral mix (3.5), L-lysine (0.5), casein (1.68), cholesterol and cholic acid (1.2; added to induce hypercholesterolemia in rats for a separate phase of this study).

TABLE III
Intestinal Responses in Rats

	Diet					
	A	B	C	D	E	F
Fiber source	Cellulose	Cellulose	Wheat	Rye	Oat	Barley
Diet intake, g	228	229	230	230	230	230
Fiber intake, g						
Total	10.5	44.9	17.0	17.5	10.6	45.1
Insoluble	10.5	44.9	15.4	14.0	7.6	34.7
Soluble	...	...	1.6	3.5	3.0	10.4
Body weight gain[a], g	62 ± 3 d	55 ± 3 e	69 ± 5 c	73 ± 3 b	77 ± 3 a	64 ± 4 d
Fecal measurements[a]						
Dry weight, g	17.6 ± 0.7 d	56.6 ± 1.0 a	22.6 ± 1.0 c	20.9 ± 1.0 c	15.2 ± 0.8 e	44.9 ± 3.5 b
Volume, cm^3	26.3 ± 2.3 d	99.5 ± 2.4 a	34.1 ± 2.1 c	27.7 ± 2.5 d	18.8 ± 2.1 e	50.3 ± 3.6 b
Density, g/cm^3	0.67 ± 0.03 d	0.57 ± 0.01 e	0.67 ± 0.03 d	0.76 ± 0.04 c	0.81 ± 0.07 b	0.92 ± 0.05 a

[a] Values are averages ± SD for 8–10 rats per diet. Within a row, means not sharing a common letter are significantly different ($P < 0.05$).

TABLE IV
Magnitude of Differences Between Fecal Weights and Volumes

	Comparison of Diets		
Parameter	A (cellulose) with E (oats)	B (cellulose) with F (barley)	C (wheat) with D (rye)
Fecal weight, g	2.4	11.7	1.7
Fecal volume, cm^3	7.5	49.2	6.4

undergoing extensive degradation by colonic bacteria (Nyman 1985, Ranhotra et al 1988), thus providing a lesser fecal weight than the highly resistant cellulose. A similar trend emerged when the wheat-based diet (diet C) was compared with the rye-based diet (diet D); the latter contained appreciably more SF than the former.

Fecal weights were poorly correlated with SF content of the diets ($r = 0.22$) but were highly correlated with TDF ($r = 0.97$) and insoluble fiber ($r = 1.00$). When related to insoluble fiber (IF) intake, fecal weight was higher (2 g per gram of IF) in rats fed the oat-based diet than in rats fed any of the other diets. However, SF in oats also contributed to fecal weight, and visualizing oats as a high fecal weight-inducing agent (in contrast to cellulose, for example) may be incorrect.

Fecal Volume

Although rats fed the cellulose-based diets yielded more fecal weight than those fed the corresponding grain-based diets, differences were even more pronounced when fecal volumes were compared (Table IV). As shown in Table III, diet A (cellulose-based) promoted about 40% greater fecal volume than did the comparable diet E (oat-based), and diet B (cellulose-based) promoted about 98% more fecal volume than did the comparable diet F (barley-based). This may mean that grain-based diets, especially if high in SF, would promote a denser fecal mass than diets high in IF.

Fecal Density

Fecal densities (calculated on the basis of dry fecal weights and volumes) in groups of rats averaged 0.57–0.92. Densities were lower in rats on the cellulose- and wheat-based diets (containing little or no SF), intermediate in rats on rye- and oat-based diets (both containing some SF), and highest in rats on the barley-based diet (containing a substantial amount of SF). These findings suggest that fecal densities would likely decrease further as higher amounts of an IF source were included in the diet.

Viewed collectively, the data suggest that higher fecal weights and volumes may be less favorably affected as the SF content of the diet increases.

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ERRATUM

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On page 336, the last two sentences of the first paragraph in Materials and Methods should read:

Color was determined using the Agtron instrument in the green mode using reference disks 68 and 97 for starch and flour, and 56 and 85 for gluten.