Comparison of Large Bowel Function and Calcium Balance During Soft Wheat Bran and Oat Bran Consumption

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ABSTRACT

This study evaluated the generally accepted concept that dietary fiber from oat bran would have less effect on stool weight than wheat bran fiber. Nine healthy young men participated in two studies, each consisting of 28 days of a low fiber diet and 28 days of a bran diet. Incorporation of 14–16 g of wheat bran or oat bran fiber into basal diets of 14–18 g of fiber increased wet and dry stool weights to the same extent and decreased fecal pH ($P < 0.05$). Neither bran changed stool moisture, gastrointestinal transit time, calcium balance, or defecation frequency. Most changes were first detected during the period from day 8 to days 12–14 of the study. Incorporation of oat bran only increased the proportion of soluble fiber in the diet from 24 to 33% of the total fiber. We conclude: 1) fiber in oat and wheat brans increases stool weight to the same extent; 2) some measures of bowel function may not change with added fiber if they are within the normal range during low fiber intakes; 3) wheat and oat brans do not adversely affect calcium balance when calcium intake is generous (≥1,200 mg/day); and 4) changes in bowel function may be detected by the second week of a dietary change if intake is rigorously controlled.

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In 1986, Cummings (1986) reviewed 94 studies from which he calculated average increases in fecal output/gram of fiber fed. These calculations suggested that oats were ≈70% as effective as wheat bran in increasing fecal output, 3.9 g/g of fiber versus 5.7 g/g of fiber, respectively. The review was updated in 1993 to cover 140 studies of the effects of different fiber sources on stool output (Cummings 1993). In this review, each gram of wheat products increased stool output an average of 5.4 g, while each gram of oat products increased stool output 3.4 g. The ability of oats to increase fecal weight was comparable to that of cellulose (3.5 g/g of fiber) and less than that for gums and mucilages (3.7 g/g of fiber) and fruits and vegetables (4.7 g/g of fiber). The most recent set of calculations suggests that oats were 63% as effective as the wheat brans in increasing stool weight. Although Cummings (1986, 1993) acknowledged that a major problem with such calculations is the lack of consistency in the methodology for dietary fiber analysis, these data nonetheless suggest that oats are considerably less effective than wheat products in modulating large bowel physiology.

Oats are considered by many to be sources of primarily soluble dietary fiber when, in fact, they rarely contain more than half of their total dietary fiber in the soluble fraction (Marlett 1993). The erroneous implication is, therefore, that as soluble dietary fiber sources, oat products would have little effect on stool weight. Two rat studies do not support such a conclusion. Mongeau et al (1990) conducted an extensive comparison of fecal pellets from rats fed hard red wheat bran and oat bran. They observed a 1.1-g increase in stool wet weight for each gram of wheat bran fed and a 1.3-g increase in fecal weight for each gram of oat bran consumed by the rats. However, wheat bran was more effective than the oat bran at increasing fecal volume (Mongeau et al 1990). Ranhotra et al (1991) compared the fecal bulking effect of four whole grain flours in rats. When their data are expressed as grams of stool per gram of dietary fiber ingested, whole wheat and whole oats have comparable effects (1.3 vs 1.4 g of dry stool wt/g of dietary fiber). In contrast, other data from rats and swine suggest that oats are less effective than wheat bran at increasing stool weight (Bach Knudsen and Hansen 1991, Nyman and Asp 1988).

Some of the differences among the literature reports may be due to the sources of the test fibers. In both reviews by Cummings (1986, 1993), the wheat category included mainly raw and cooked bran, whereas the oats category included both rolled oats and oat bran. Rolled oats contain less fiber than the bran (Marlett 1993). A commercial oat bran cereal was the source of oat bran used in the studies suggesting that oat bran increased stool weight less than wheat bran (Nyman and Asp 1988, Bach Knudsen and Hansen 1991). The dietary fiber composition of that particular commercial oat bran cereal suggests that other fiber sources had been added to the product (Marlett 1993). Although oats are well known for their hypocholesterolemic effects (Anderson 1995), demonstration of their stool bulking ability, in comparison to that of wheat products, would document an additional health benefit of consuming whole oats or oat bran fiber sources.

In contrast, untoward effects of fiber supplements on mineral nutriture would not be beneficial. Both wheat bran and oat bran contain phytate (Harland 1993), which reduces mineral absorption under some circumstances (Rossander et al 1992). Calcium nutriture has been proposed to be adversely affected by some fiber supplements (Marlett 1984, Pilch 1987), and the chances for this might be greater if a relatively large amount of a single fiber source that also contains phytate was consumed.

Although differences in dietary fiber methodology or sources may be responsible for the lower stool bulking effects of oats versus wheat in humans demonstrated by Cummings (1993), it is also possible that differences or inadequacies in experimental design might be responsible. Perhaps measurements were made too soon after the diet change was initiated or for too short a period of time to reflect the full response to consumption of the particular fiber source. A short study period also could be responsible for the inconsistent effects of fiber on mineral nutriture.

The objectives of this research were: 1) to determine the effects on large bowel physiology and calcium balance of incorporating comparable amounts of wheat bran and oat bran fiber into constant diets composed of conventional foods; 2) to compare the large bowel responses to wheat bran versus oat bran incorporated in the diets; 3) to evaluate the effect of study duration on the large

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the diets; and 4) to determine the proportion of soluble dietary fiber consumed when relatively large amounts of oat bran were incorporated in a low fiber diet.

MATERIALS AND METHODS

Experimental Protocol

Two studies of similar design were conducted. Each study consisted of a low fiber control period and a fiber-supplemented period. A constant low fiber diet composed of conventional foods was consumed for 28 days. The same diet which incorporated the fiber supplement was consumed during the subsequent 28-day period (29-56). The studies did not employ a crossover or randomized design, because existing evidence indicated carryover effects resulting from diet change (Heller et al 1980). All urine and feces excreted throughout all periods were collected. Experiments were approved by College of Agricultural and Life Sciences Committee on Human Subjects, University of Wisconsin-Madison.

Subjects

Nine male subjects, recruited by local advertising, volunteered for each study and gave informed consent. The subjects had no chronic medical conditions, normal blood lipid levels, consumed mixed diets similar to those consumed by the U.S. population that were moderate to low in dietary fiber content, did not require habitual medication, and did not use tobacco. They were college age, healthy men of normal weight for height (Table I). Body weights were recorded daily. Initial body weights were maintained throughout each two month study by adjusting daily caloric intake as needed (Table I).

Diets

Basal, low fiber, two-day cycle menus were developed for the wheat bran study that contained 2,600 kcal/day, 15% of the kcal as protein, 35% as fat, and 50% as carbohydrate (Table II). The basal two-day cycle menus for the oat bran study contained 2,700 kcal and amounts of carbohydrate, protein and fat comparable to those in the wheat bran menus (Marlett et al 1994). Additions (200 kcal) for the wheat bran and additions (300 kcal) for the oat bran that contained little fiber were constructed to meet additional energy needs without changing the proportions and kinds of macronutrients (Table II). Wheat bran (30 g/day) (soft white, American Association of Cereal Chemists, St. Paul, MN) and oat bran (100 g/day) (donated by the Quaker Oats Co., Barrington, IL) were incorporated into the basal diets through specially developed recipes for bread, muffins, cookies, salisbury steak, and meatballs that were prepared in quantity. Some of the oat bran was consumed in the form of a ready-to-eat cereal. Other grain-derived starch in the high fiber period was reduced, and gluten was added to the low fiber periods to keep vegetable protein contents of the low and high fiber periods comparable. The fat content of the oat bran diet was adjusted to account for the fat contributed by that bran.

All food for each study, except for fresh produce and dairy products, was purchased as single lots, prepared and frozen or stored until prepared. All food was individually portioned to the nearest gram in a metabolic kitchen, prepared if not previously done, and served in a metabolic dining room. All food was consumed. Deionized, distilled water was consumed ad libitum.

Energy consumed during the wheat bran study ranged from 2,600–3,600 kcal/day and 2,700–3,600 kcal/day for the oat bran study (Table II). The diets were also constructed to provide comparable lipids and carbohydrates across the range of caloric intake (Table II). Micronutrient intake met or exceeded the Recommended Dietary Allowances (NAS 1980) for calcium, phosphorus, iron, vitamins A and C, thiamin, riboflavin, niacin, folate, and zinc (Watt and Merrill 1963, Adams 1978, Paul and Southgate 1978). Sodium intake ranged from 3.7 to 6.3 g/day and potassium intake ranged from 3.3 to 6.2 g/day.

TABLE I
Selected Characteristics of Healthy Men Participating in Dietary Fiber Studies

Characteristics	Study Incorporating	
	Wheat Bran	Oat Bran
No. of subjects	9	9
Age, yr.		
Mean ± SD	22.8 ± 2.5	23.8 ± 2.2
Range	19–27	20–28
Height, cm		
Mean ± SD	178.1 ± 7.4	178.6 ± 4.6
Range	167.6–190.5	172.7–182.8
Body mass index		
Mean ± SD	22.5 ± 0.6	22.7 ± 1.5
Range	19.9–25.3	20.7–25.3
Energy intake, kcal		
Range	2,600–3,600	2,700–3,600
Body weight, kg[a]		
Week 1	72.2 ± 8.2	72.6 ± 6.4
Week 4	71.7 ± 7.7	72.1 ± 6.4
Week 8	71.2 ± 6.9	72.0 ± 6.3

[a] Mean ± standard deviation (SD) of 7 days

TABLE II
Range of Nutrient and Energy Intake in Two-Day Cycle Menus from Two Metabolic Studies[a]

Diet component	Wheat Bran		Oat Bran	
	Without	With	Without	With
Kilocalories	2,595–3,187	2,590–3,608	2,667–3,607	2,661–3,629
Protein, g	97–120	97–134	100–133	100–134
% kcal	15	14–15	15	15
Fat, g	101–126	101–142	105–139	105–139
% kcal	35	35	34–35	34–35
Carbohydrate, g	326–398	325–463	336–468	338–468
% kcal	50	50–51	50–51	50–51
Cholesterol, mg/1,000 kcal	123–150	124–151	112–124	110–119
% Total fat				
Saturated fat	25–29	26–29	24–28	24–26
Oleic acid	36–38	33–39	35–38	32–36
Linoleic acid	25–28	25–28	26–27	24–26
% Total carbohydrate				
Starch	54–58	50–54	49–59	48–56
Endogenous sugar	19–24	21–25	21–28	20–27
Sucrose	20–25	24–26	15–24	16–28

[a] Calculated from published data (Watt and Merrill 1963, Adams 1975, Paul and Southgate 1978), except for selected values for which label data were used.

TABLE III
Dietary Fiber Composition (% dwb) of Wheat Bran and Oat Bran

	β-Glucans	Neutral Sugars	Uronic Acids	Klason Lignin	Total
Wheat bran					
Soluble[a]	···	1.3	0.1	0	1.4
Insoluble	···	41.3	1.4	3.5	46.2
Oat bran					
Soluble	4.9	2.4	0.2	0	7.5
Insoluble	1.3	4.3	0.3	2.8	8.7

[a] Fiber fractions obtained by a modification of the Theander chemical method A (Shinnick et al 1988).

Fecal Collections and Analyses

Each stool was individually collected into a plastic carton lined with a plastic bag. The carton was immediately covered with a snap-on lid, refrigerated within 2 hr of collection, weighed, and frozen (−10°C) within 8 hr of collection. Within the month following each study, samples were removed from the freezer, reweighed, blended to homogeneity with distilled water, and lyophilized to determine dry weight and for subsequent chromium and calcium analyses. The fresh and frozen weights were the same. Excretion of 70% of doses of chromium consumed with breakfast as 1 g of chromic oxide at the beginning of the second, third, and fourth weeks of each study period, was the measure of gastrointestinal transit time (Marlett et al 1986).

Chromium in individual stools was analyzed in duplicate, 1-g dry aliquots by a method adapted from Guncaga et al (1974), in which the amount of concentrated sulfuric used for digestion was decreased from 5.0 to 2.5 ml to eliminate sulfuric acid interference with spectrophotometric readings. Completeness of fecal collections was assessed by determining recovery of the ingested chromium. Mean (± standard deviation) recovery of 54 doses administered during the wheat bran study was 97 ± 3%. Mean (± standard deviation) recovery of 54 doses administered during the oat bran study was 91 ± 6%.

Calcium excretion was measured by combining lyophilized feces into representative composites of two 10-day periods (days 18-27 and days 46-55) during each study. Calcium was measured by atomic absorption spectrophotometry (Slavin and Marlett 1980).

One stool was collected from each subject during the last week of each diet period under a stream of nitrogen for immediate anaerobic pH (Orion model 4100-15 probe) and reduction-oxidation potential (Orion model 97-78-00 probe) determinations. This collection was accomplished in the laboratory by using a portable hospital stool placed over a large container lined with a

TABLE IV
Dietary Fiber Composition of Daily Menus[a]

	% Neutral Sugars					% dwb					g/day
Fiber	Glc	Xyl	Gal	Ara	Man	β-glucan	Neutral Sugars	Uronic Acids	Klason Lignin	Total	Total Fiber
Wheat bran[b]											
Low fiber											
Soluble	20	30	19	26	5	0	0.5	tr[c]	0	0.5	
Insoluble	55	14	11	12	8	0	2.0	0.4	0.5	2.9	18.2
High fiber											
Soluble	15	33	18	28	6	0	0.5	tr	0	0.5	
Insoluble	42	31	4	18	5	0	3.6	0.4	0.7	4.7	28.8
Oat bran[d]											
Low fiber											
Soluble	12	27	30	26	5	0	0.5	0.1	0	0.6	
Insoluble	60	12	6	11	11	0	1.3	0.2	0.4	1.9	13.6
High fiber											
Soluble	62	8	15	12	3	0.9	0.5	0.2	0	1.6	
Insoluble	50	19	9	14	8	0.2	1.9	0.3	0.9	3.3	27.9

[a] Dietary fiber determined as described in Table III.
[b] Mean of the two days of the cycle menu containing 2,600 kcal; additional soluble and insoluble fiber, respectively: 0.2 and 0.3 g in 2,800 kcal menus (mean of two days); 0.5 and 2.0 g in 3,000 kcal menus; 0.6 and 2.1 g; in 3,200 kcal menus; 0.8 and 2.5 g in 3,600 kcal menus.
[c] Trace.
[d] Mean of the two days of the cycle menu containing 2,700 kcal; each additional 300 kcal intake contained (mean of two days) 0.3 g soluble and 1.3 g insoluble fiber.

TABLE V
Effect of Study Duration on Measures of Large Bowel Function[a]

	Days of Study,[b] Without Added Fiber				
Measure	8–12	13–17	8–17	18–27	8–27
Wheat bran					
Daily wet SW (g)	94.0 ± 11.7a	78.1 ± 32.1a	86.1 ± 16.8a	82.7 ± 18.0a	85.4 ± 14.5a
Daily dry SW (g)	26.3 ± 2.6α	22.8 ± 8.6a	24.6 ± 4.4a	24.6 ± 3.4a	24.6 ± 2.7a
Wet wt/stool (g)	159.3 ± 63.7	135.5 ± 46.9	147.5 ± 53.4	150.8 ± 70.5	148.6 ± 60.8
Dry wt/stool (g)	45.3 ± 19.9	40.9 ± 16.3	43.1 ± 17.7	44.4 ± 20.9	43.8 ± 18.6
Stool moisture (%)	71.2 ± 2.7	69.9 ± 4.2	70.6 ± 3.4	70.4 ± 4.1	70.5 ± 3.6
Defecation frequency (no./day)	0.7 ± 0.3	0.6 ± 0.3	0.7 ± 0.3	0.7 ± 0.3	0.7 ± 0.3
GI transit time (hr)	63.6 ± 23.2b	···	69.3 ± 20.2a,b	83.0 ± 28.0a	76.6 ± 20.9a,b
Oat bran					
Daily wet SW (g)	100.8 ± 42.5c	121.7 ± 19.2b,c	111.3 ± 21.8c	108.7 ± 27.4c	110.9 ± 21.4c
Daily dry SW (g)	27.1 ± 8.0a	32.2 ± 4.9a	29.7 ± 3.0a	28.8 ± 4.6a	29.3 ± 3.2a
Wet wt/stool (g)	126.2 ± 31.8c	137.4 ± 45.0b,c	132.0 ± 35.4c	130.9 ± 29.4c	131.5 ± 31.3c
Dry wt/stool (g)	34.8 ± 8.7c	36.3 ± 10.6b,c	35.6 ± 9.3c	35.5 ± 8.5c	35.5 ± 8.5c
Stool moisture (%)	71.7 ± 2.7	73.1 ± 2.6	72.3 ± 2.4	72.0 ± 2.9	72.2 ± 2.4
Defecation frequency (no./day)	0.8 ± 0.4	0.9 ± 0.2	0.9 ± 0.3	0.9 ± 0.2	0.9 ± 0.2
GI transit time (hr)	65.5 ± 16.2a	···	59.0 ± 14.3a,b	62.5 ± 11.7a,b	63.5 ± 11.9a,b

[a] Data were collected during two, 56-day, constant diet studies that consisted of 28 days of low fiber diet (days 1–28) and 28 days in which wheat (30 g/day) or oat (100 g/day) bran was incorporated into the low fiber diet, increasing fiber intake from 18 to 29 g/day and 14 to 28 g/day, respectively. All data were collected in 5-day periods, except for transit time which was collected in 7-day periods. SW = stool weight, GI = gastrointestinal. Data in a row with different letters are significantly different ($P < 0.05$).
[b] Data are expressed as means of those collected over periods of 5, 10, and 20 days to evaluate the effects of study duration on the measure.

plastic bag. The bag was flushed with nitrogen and the stream of gas was continued until the reduction-oxidation potential and pH were measured in three separate locations in the excreted stool; the three determinations from each stool were averaged.

Urine Collection and Analyses

Complete daily urine collections were made and analyzed for creatinine to verify completeness of the collection (Slavin and Marlett 1980). Urine was then composited as outlined for stool collections and calcium concentration determined by atomic absorption spectophotometry.

Diet Collection and Dietary Fiber Analysis

During the second week of each diet period, aliquots of all fiber-containing foods equivalent to the amounts in the basal menus were weighed out, homogenized to uniformity, and lyophilized for subsequent dietary fiber analysis. Dietary fiber content and composition of the menus and of the fiber sources was determined by a modification (Shinnick et al 1988) of the Theander Chemical Method A (Theander and Westerlund 1986). 1→3,1→4 β-D-glucans were measured by the method of McCleary and Glennie-Holmes (1985).

The wheat bran contained 47.6% dietary fiber, most of which was insoluble, and oat bran contained 16.2% total fiber, 38% of which was β-glucans (Table III). The neutral sugar (galactose, arabinose, xylose, mannose, and glucose) distribution in the insoluble and soluble fractions of the fiber sources were similar to those previously reported (data not shown) (Marlett 1993).

Statistics

All data are expressed as the mean ± standard deviation. Statistical significance was determined by one-way analysis of variance (ANOVA) (SAS, release 6.09, 1989, Cary, NC). Comparisons between the studies of the two fiber sources were made by unpaired *t*-test. Comparisons of the changes in bowel function that occurred with incorporation of the two fibers in the diets were made as the difference between the results measured during days 8–27 (control period) and days 36–55 (fiber period), divided by the control period data, and expressed as a percentage. When significant ($P < 0.05$) differences were observed, means were compared by the Fischer's protected least significant difference (LSD) method.

RESULTS AND DISCUSSION

Dietary Fiber Intake with Bran Incorporation

The average (of the two-day cycle menus) daily intake of fiber during the control diets was 18 g for the wheat bran study and 14 g for the oat bran study when the basal energy level of 2,600 or 2,700 kcal was consumed (Table IV). Insoluble dietary fiber was the major fiber fraction in both sets of control menus, accounting for 85% of the total in the wheat bran control and 76% of the total in the oat bran control diets. Incorporation of 30 g/day of wheat bran increased total fiber intake by 62% to 29 g and, as expected, only the insoluble fiber fraction was increased. Incorporation of 100 g/day of oat bran doubled the average daily dietary fiber intake and produced a 2.5-fold increase in soluble dietary fiber intake. However, because oat bran also contributed substantial insoluble dietary fiber, the proportion of soluble fiber was only increased from 24 to 33%. This result clarifies a common misconception that adding oat products to a diet will significantly increase the soluble dietary fiber intake.

Menus had been developed using dietary fiber values for individual foods (Marlett 1992) that were determined using the same Theander Method A modification (Shinnick et al 1988) used in this study, with the aim of providing 15 g/day of dietary fiber. The dietary fiber content and composition of the daily menus were determined to verify these calculations. Based on the analysis of the oat fiber source, 100 g of oat bran provided 16.2 g of dietary fiber; the sum of the dietary fiber in the control diet (13.6 g) and the fiber in the daily allotment of oat bran is 29.8 g, which agrees with the value obtained by analysis of the menus from the oat bran period (27.9 g).

In contrast, the analyzed and calculated dietary fiber contents of the wheat bran menus did not agree. The sum of the fiber provided by 30 g/day of wheat bran (14.3 g) and the fiber measured in the wheat bran control diet (18.2 g) is 32.5 g, which is higher than the analyzed value of 28.8 g. Although the recipes for the yeast bread, quick breads (molasses, banana, and cheddar cheese muffins), and cookies (peanut butter and chocolate chip) were very similar for both studies, these home-prepared foods for each study were prepared at separate times using different lots of ingredients. In addition, the oat bran had more gluten and fat than the wheat bran. Ingredients or baking conditions have been

TABLE V (*continued*)

Days of Study,[b] With Added Fiber				
36–40	**41–45**	**36–45**	**46–55**	**36–55**
134.0 ± 33.2b	135.0 ± 26.9b	134.5 ± 24.7b	138.1 ± 26.2b	136.3 ± 23.5b
37.1 ± 6.6b	37.6 ± 5.6b	37.4 ± 3.9b	38.4 ± 4.8b	37.9 ± 3.8b
163.2 ± 79.6	162.8 ± 58.4	163.0 ± 68.3	166.7 ± 56.2	164.9 ± 58.8
45.7 ± 21.0	45.8 ± 15.5	45.8 ± 18.1	47.2 ± 17.4	46.5 ± 16.8
71.4 ± 3.2	71.5 ± 3.5	71.5 ± 3.3	71.3 ± 3.2	71.4 ± 3.1
0.9 ± 0.3	0.9 ± 0.3	0.9 ± 0.3	0.9 ± 0.3	0.9 ± 0.3
62.9 ± 17.3b	···	60.2 ± 14.8b	63.4 ± 18.2b	63.3 ± 13.7b
143.6 ± 35.8a,b	161.0 ± 36.9a	152.3 ± 29.2a	165.9 ± 34.6a	159.1 ± 28.7a
40.5 ± 10.4b	43.6 ± 8.2b	42.1 ± 6.7b	43.3 ± 5.8b	42.7 ± 5.3b
183.6 ± 53.0a	184.4 ± 73.5a	184.0 ± 61.3a	179.4 ± 54.4a,b	181.7 ± 55.6a,b
51.2 ± 12.6a	49.5 ± 16.6a	50.4 ± 13.7a	47.0 ± 11.1a,b	48.7 ± 11.6a
71.6 ± 2.7	72.1 ± 2.7	71.8 ± 2.6	72.9 ± 2.7	72.4 ± 2.5
0.8 ± 0.3	1.0 ± 0.3	0.9 ± 0.3	1.0 ± 0.2	0.9 ± 0.2
55.8 ± 14.6a,b	···	52.1 ± 10.7b	51.4 ± 14.1b	52.6 ± 11.0b

shown to increase the dietary fiber content of a food (Vollendorf and Marlett 1994), and it is possible that either could have inflated the fiber value obtained for the control diet during the wheat bran study.

Bowel Function with Bran Incorporation

Both brans increased mean daily wet and dry stool weights but had no effect on stool moisture (Table V). These data are in agreement with other findings (Cummings 1993). When stool weight increases, either defecation frequency or the average weight of each stool must increase. In the present study, oat bran significantly increased the weight of each stool, but not defecation frequency. Wheat bran had small effects on both mean weight of each stool and on defecation frequency but, because the changes were distributed between both parameters, neither change was statistically significant.

Gastrointestinal transit time was not consistently decreased by consumption of either bran. It is generally agreed that normal transit time is 2–3 days (Pilch 1987), and since normal transit rates were observed during the control periods, a failure to see a decrease with bran consumption is not unexpected. When total gastrointestinal transit is longer than 3 days, both types of bran usually decrease transit (Pilch 1987, Cummings 1993).

Consumption of either bran decreased fecal pH ($P < 0.05$). Mean (± standard deviation) fecal pH values during the last week of the control and wheat bran diet periods were 6.9 ± 0.2 and 6.6 ± 0.3; during the control and oat bran periods the pH values were 6.6 ± 0.32 and 6.3 ± 0.4. Fecal reduction-oxidation potentials were not changed significantly by either fiber source. Values for the control and fiber periods, respectively, were: –271 ± 49 and –287 ± 79 (wheat bran experiment) and –267 ± 74 and –267 ± 67 (oat bran experiment).

Calcium Balance with Bran Incorporation

Neither bran significantly changed calcium balance, perhaps because calcium intake of our subjects was above that generally recognized as needed to maintain balance in young healthy males (Table VI). Overall the effect of dietary fiber on mineral balance has been variable (Pilch 1987, Gordon 1988, Rossander et al 1992). This may be due to differences in fiber sources, the composition of the basal diet, the amount of calcium consumed, the duration of the study, and possibly the form of calcium. The diet, and thus chyme in the small bowel, is extraordinarily complex, and some of the effects of fiber on mineral nutriture that have been observed using relatively simple, in vitro systems probably would not occur in vivo (Rossander et al 1992). Concern remains, however, for those groups within the population, such as the elderly, who may not consume adequate calcium and may use concentrated fiber sources to help regulate bowel function (Balasubramanian et al 1987).

Study Duration

Our results indicate that changes in stool weight, moisture, and frequency occur promptly after an increase in dietary fiber intake is instituted. These changes are observed during the second week of the diet modification (Table V). Furthermore, they can be detected by measuring the change over a 5-day period. Although the actual values from the different periods of time varied, increasing the length of the collection period to 10 or 20 days revealed no additional statistically significant differences. We previously demonstrated that if collection periods shorter than 5 days are used, the results may not be representative (Marlett et al 1986).

No change in gastrointestinal transit time was observed when oat bran was incorporated into the diet, regardless of the duration of the data collection period (Table V). During the wheat bran study, analysis of the data from only one of the four collection periods (days 18–27 after the diet change was instituted) revealed an effect on gastrointestinal transit time. Measurement of transit time is difficult because it is substantially influenced by voluntary control of defecation, which leads to random variation (Pilch 1987). Our data suggest that differences of 20 hr are needed to produce a significant difference. Voluntary retention for >12 hr of that fraction of a quantitative marker used as the measure of transit (such as the 70% of chromium used here) would negate statistical significance. We observed during the study that subjects frequently waited to use laboratory facilities for stool collections because of their convenient location to necessary refrigeration for samples.

Comparing Wheat Bran and Oat Bran Responses

Our results indicate that when comparable amounts of fiber are consumed, the effects of oat bran on wet and dry stool weight, stool moisture, gastrointestinal transit time, and fecal pH (Fig. 1) were similar to the effects of wheat bran. The extensive review and summary by Cummings (1993) may have shown less response with oats, because in contrast to wheat bran, different forms of oats with different fiber contents (e.g., oat hulls, oat bran, oatmeal) have been used as the fiber source. The two brans did have significantly different effects on defecation frequency and average weight of each excretion.

CONCLUSIONS

Our results clearly demonstrate that comparable amounts of dietary fiber from oat bran and wheat bran produce similar changes in stool weight. There are three possible explanations for previous observations that oat bran is less effective. First, fiber analysis data suggest that inclusion in the oat bran category of fiber sources that are not oat bran would be one reason why it appears to increase stool weight less than wheat bran. Second, as Cummings (1986, 1993) cautioned, there are differences in methods of fiber analysis. An overestimation of oat bran fiber would decrease its apparent effect on stool weight when presented as the increase in stool weight per gram of fiber consumed. Third, oat bran might appear to be less effective than wheat bran as a result of differences in fermentation. Oat hulls, frequently called oat fiber, are poorly fermented (Lopéz-Guisa et al 1988). If included in the previous observations, it is likely that oat hulls would have an effect on stool weight similar to that of purified cellulose, which is also poorly fermented (Slavin et al 1981, Lopéz-Guisa et al 1988), and less effect than a comparable amount of wheat bran and oat bran, which are fermented.

Table VI
Effect of Dietary Fiber on Calcium Balances of Healthy Young Men[a]

Diet	Calcium, mg/day			
	Intake	Fecal	Urine	Balance
Control	1,424 ± 23	1,237 ± 172	173 ± 69	13 ± 205
Control with wheat bran	1,421 ± 41	1,326 ± 99	156 ± 69	–61 ± 83
Control	1,326 ± 33	1,186 ± 126	228 ± 73	–84 ± 85
Control with oat bran	1,450 ± 40	1,336 ± 92	168 ± 64	–54 ± 61

[a] Mean ± standard deviation, $n = 9$, of last 10 days of 4 weeks of constant diet period for each study.

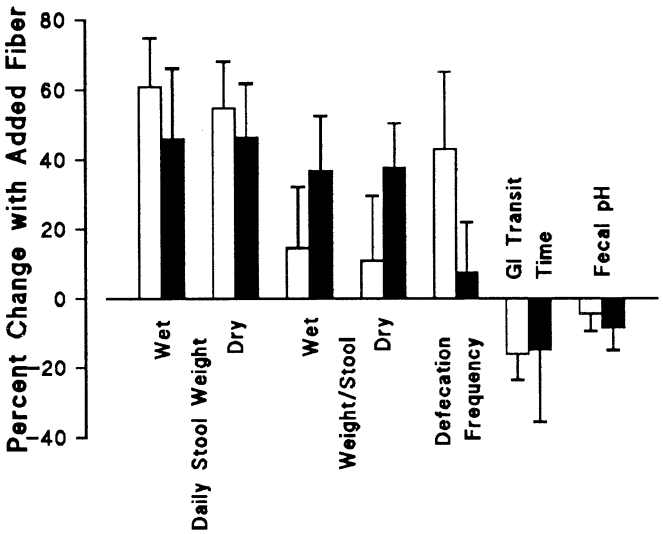

Fig. 1. Comparisons of large bowel responses with wheat (open bars) and oat (closed bars) bran incorporation into constant low fiber diets. Comparisons of the changes in bowel function that occurred with the brans were calculated as the difference between the results measured during the control period (days 8–27) and bran period (days 36–55) divided by the control period data and expressed as a percentage.

Our observation that significant changes in large bowel function induced by increasing fiber intake can be detected after one week needs to be applied cautiously to future experimental designs. The promptness and statistical significance of these responses were enhanced by minimizing sources of variability which, in this study, included the use of a constant diet and paired observations. However, controlling for these sources of variation substantially increases the cost of an experiment. Larger numbers of subjects and a study period longer than two weeks may be necessary if these major sources of variation in studies of large bowel function are not controlled. Such short term studies also do not address any longer term changes that might occur as a result of microbial adaptation to the diet.

Stool moisture is remarkably constant and ≈70–75% over a range of fiber intake (Eastwood et al 1980). Exceptions include situations of severe constipation where stool moisture contents of <70% are observed (Marlett et al 1987, Liebl et al 1990). Stepwise increases in the consumption of a non- or partially fermented fiber would produce stepwise increases in stool weight (Lopéz-Guisa et al 1988). In contrast, it was postulated in 1973 that defecation frequency and gastrointestinal transit would be normalized by added fiber (Harvey et al 1973). This modulation of large bowel function was evident in our studies.

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