Nutritional Properties of Coarse and Fine Sugar Beet Fiber and Hard Red Wheat Bran. I. Effects on Rat Serum and Liver Cholesterol and Triglycerides and on Fecal Characteristics

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ABSTRACT

The object of the experiment was to determine the effects of coarse and fine sugar beet fiber and coarse wheat bran compared with cellulose on rat weight gains, serum and liver lipids, and fecal weight and water-holding capacity. No significant differences were found in overall weight gains or feed efficiencies with diets containing the various fibers at the 5% level of supplementation. By the end of the sixth week, total serum cholesterol levels were lower in animals fed beet fiber diets than in those fed the cellulose diet, and the lowering effect was not at the expense of high-density lipoprotein cholesterol. No dose-response effect of beet fiber was noted, however. Animals fed the 5% wheat bran diet had cholesterol levels intermediate between those of animals fed cellulose and beet fiber. In general, our results corroborate those of other investigators, who have found little or no hypocholesterolemic effect of dietary wheat fiber. Increasing levels of beet fiber also resulted in reduced liver cholesterol pools. At the end of week 6, serum triglyceride concentrations did not differ significantly among groups, but rats fed sugar beet fiber had lower liver triglyceride concentrations (which appeared to be concentration related) than those fed cellulose or wheat bran. Coarse beet fiber appeared to have a greater effect than fine beet fiber. No differences were found in fecal water-holding capacity among rats fed wheat bran and coarse and fine beet fiber at the 5% level of supplementation, but feces of rats fed 5% cellulose had a significantly lower water-holding capacity. Beet fiber particle size appeared to have no effect on wet or dry feces weight or water-holding capacity. In general, these results show that sugar beet fiber has potential as a dietary aid in the treatment of hypercholesterolemia and constipation.

The search for dietary means to lower blood cholesterol levels has intensified recently because there is no longer any doubt that reducing blood cholesterol concentration reduces the risk of heart disease (National Institutes of Health 1985, American Heart Association 1986, Thompson 1987). Some investigators advise therapy for individuals with blood cholesterol levels as low as 200 mg/dl (DeBakey et al 1986, Roberts 1987). Treatment usually consists of severe restriction of dietary fat and cholesterol, often in conjunction with drug therapy, which is notoriously unpleasant and expensive (Roberts 1987). It has been estimated that the cost per year of life saved with cholestyramine therapy is $117,400, compared to $17,800 for treatment with cholesterol-lowering dietary plant fiber (Kinosian and Eisenberg 1988).

The fact that some water-soluble plant polysaccharides, including pectins, can lower serum and tissue cholesterol levels is now well established (Anderson and Chen 1979, Kritchevsky 1986, Miettinen 1987, Reiser 1987). Sugar beet fiber (the dried pulp or residue of beets after the sugar has been extracted) contains nearly 20% soluble fiber, most of which is pectin (Nyman and Asp 1982, Phatak et al 1988). One study showed that rats fed sugar beet fiber had lower cholesterol levels than rats fed wheat bran but not significantly lower levels than animals fed cellulose fiber (Forsythe et al 1978).

Most reports indicate that wheat bran, which is composed mainly of insoluble cellulose and hemicelluloses, with only about 5% soluble fiber, has little hypocholesterolemic effect, but conflicting data continue to appear (Kay and Truswell 1980, Kies 1985). Dietary cellulose alone at concentrations as high as 15% has been shown not to affect serum cholesterol levels in rats fed casein-based diets (Ogunwole et al 1987).

Another health aspect of dietary fiber, especially highly insoluble fiber, is that it functions as an intestinal bulking agent. In 1985, Anderson reported that constipation was a major problem for Americans, who spent more than $400 million for over-the-counter laxatives and stool softeners. In addition, constipation often leads to more serious problems, such as diverticular disease or hemorrhoids. In many experiments comparing the bulking effects of various fibers, wheat bran has been found to be one of the best fecal bulking agents (Cummings 1982).

The effect of fiber particle size on physiological activity and physicochemical properties of fibers is not clear. Forsythe et al (1978) reported that particle size of wheat bran and cellulose had no effect on wet fecal mass or water-holding capacity but that serum cholesterol increased in rats fed coarser bran. Conversely, Van Soest (1984), Kirwan et al (1974), and Schneeman (1986) reported that bran particle size had a significant effect on fecal characteristics.

The object of the experiment described here was to determine the effects of coarse and fine sugar beet fiber and coarse wheat bran, compared to the effects of cellulose, on rat weight gains, serum and liver lipids, and fecal weight and water-holding capacity.

MATERIALS AND METHODS

Eight groups of 10 male Wistar rats, each weighing 91.2 ± 2.3 g (mean ± SD) (Charles River Breeding Laboratory, Wilmington, MA), were fed casein-based diets containing α-cellulose, hard red winter wheat bran (AACC reference sample), or dried sugar beet fiber for six weeks (Table I). Diets and water were provided ad libitum. Proximate analysis of the diets showed them to contain 16.6 ± 0.2% protein (N × 6.38), 5.0 ± 0.2% fat, and 3.23 ± 0.18% ash. Particle sizes and surface areas of the fibers used are shown in Table II. Size and area of the fine beet fiber were similar to those of cellulose; those of the coarse beet fiber were similar to those of the wheat bran. Total dietary fiber (TDF) and soluble fiber contents of the diets were: for the 5% cellulose diet, 9.64 and 0.40%; for 5% wheat bran, 6.64 and 0.48%; for 5% beet fiber, 7.83 and 1.01%; for 7.5% beet fiber, 9.74 and 1.31%; and for 10% beet fiber, 11.7 and 1.61%, respectively (Sigma Total Dietary Fiber Assay Kit, based on a modification of the method of Prosky et al 1988). Levels of TDF in the 5% fiber-substituted experimental diets were similar to levels suggested for humans (4.2–6.4% dry basis). The calculation is based on the recommended dietary fiber intake for humans (20–30 g/day, NCI 1987) and the average adult male energy allowance (2,900 kcal/day, NRC/NAS 1989) and assumes that 35% of the kilocalories are supplied by fat.

Animals were individually housed in metabolism cages in an environmentally controlled room (22°C, 12-hr light-dark cycle). Animals were weighed weekly; feed consumption records were kept, and feed efficiencies were calculated. Feces were collected daily during weeks 3 and 6. At each daily collection, feces were placed in styrofoam cups with close-fitting lids, then frozen until the next collection. Moisture content of the entire feces sample

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TABLE I
Diet Composition for Rats Fed Cellulose, Wheat Bran, or Sugar Beet Fiber

Ingredient (% of diet)	Cellulose 1	Wheat Bran 2	Sugar Beet Fiber 3 and 4	Sugar Beet Fiber 5 and 6	Sugar Beet Fiber 7 and 8
Vitamin-free casein[a]	18.9	17.4	17.7	17.5	17.3
Cornstarch[a]	15.9	18.2	17.2	14.9	12.6
Sucrose	49.0	49.0	49.0	49.0	49.0
Soybean oil	5.2	4.4	5.1	5.1	5.1
Cellulose[b]	5.0	...	...	...	...
Wheat bran[c]	...	5.0	...	...	...
Sugar beet fiber[d]	...	...	5.0	7.5	10.0
AIN vitamin mix[e]	1.0	1.0	1.0	1.0	1.0
AIN mineral mix[e]	3.5	3.5	3.5	3.5	3.5
Choline bitartrate[a]	0.2	0.2	0.2	0.2	0.2
DL-Methionine[a]	0.3	0.3	0.3	0.3	0.3
Cholesterol[f]	1.0	1.0	1.0	1.0	1.0
Calculated kcal/100 g[g]	391	397	394	386	377

[a] Sigma Chemical Co., St. Louis, MO.
[b] Alphacel, ICN Nutritional Biochemicals, Cleveland, OH.
[c] AACC certified hard red wheat bran, AACC, St. Paul, MN. Total dietary fiber, 52.8%; soluble dietary fiber, 4.0%.
[d] Dried sugar beet pulp, The Amalgamated Sugar Company, Ogden, UT. Total dietary fiber, 76.6%; soluble dietary fiber, 16.0%.
[e] American Institute of Nutrition mixes, ICN Nutritional Biochemicals, Cleveland, OH.
[f] USP/NF Cholesterol (95%), Sigma Chemical Co., St. Louis, MO.
[g] Using the value of 0.68 kcal/g (provided by The Amalgamated Sugar Company) for sugar beet fiber and 2.19 kcal/g (AACC certification value) for wheat bran.

TABLE II
Particle Sizes of Fiber Sources Used in Experimental Diets[a]

Diet	Fiber	Geometric Mean Diameter (μm)	Standard Deviation (μm)	Surface Area (cm²/g)
1	Cellulose	179	1.69	367
2	Wheat bran	492	1.66	131
3,5,7	Fine sugar beet fiber	185	1.62	347
4,6,8	Coarse sugar beet fiber	436	1.77	154

[a] Particle size was determined using the American Society of Agricultural Engineers sieving method (ASAE 1987).

TABLE III
Overall Weight Gains and Feed Efficiencies of Rats Fed Cellulose, Hard Red Wheat Bran, and Coarse and Fine Sugar Beet Fiber[a]

Diet No.	Diet Type	Weight Gain (g)	Feed Efficiency (feed/gain)
1	5% Cellulose	263 ab	0.311 ab
2	5% Wheat bran	255 ab	0.309 ab
3	5% Fine beet fiber	257 ab	0.317 a
4	5% Coarse beet fiber	260 ab	0.307 ab
5	7.5% Fine beet fiber	276 a	0.313 ab
6	7.5% Coarse beet fiber	256 ab	0.297 abc
7	10% Fine beet fiber	248 ab	0.289 bc
8	10% Coarse beet fiber	243 b	0.275 c

[a] Means in the same column not followed by the same letter are significantly different at $P < 0.05$.

was determined by drying to constant weight in an air oven at 60°C, then subtracting feces dry weight from feces wet weight.

Blood samples were drawn by cardiac puncture from ether-anesthetized animals at the end of weeks 3 and 6. Blood was allowed to clot at room temperature, then was centrifuged at 12,000 × g at 5°C for 15 min. All serum samples were analyzed in duplicate for total and high-density lipoprotein (HDL) cholesterol and triglycerides using reagents from Sigma Chemical Co., St. Louis, MO (Kits No. 352, 352-3, and 339, respectively).

After six weeks of feeding, the animals were sacrificed by placing them in an ether atmosphere. Their livers were quickly removed, rinsed under cold tap water, blotted dry, weighed, and frozen. Lipids were extracted with chloroform-methanol (Klopfenstein and Clegg 1980). An aliquot of the extract was evaporated to dryness under nitrogen; the lipid residue, redissolved in absolute ethanol, was used for determination of total liver cholesterol (Rosenthal et al 1957).

The data were statistically evaluated by the analysis of variance procedure with Duncan's test using the Statistical Analysis System (SAS 1985) 5.16 at Kansas State University, Manhattan.

RESULTS AND DISCUSSION

Effects of Fiber on Rat Weight Gains, Feed and Caloric Intakes, and Feed Efficiencies

No significant differences were found in overall weight gains or feed efficiencies associated with diets containing 5% cellulose, 5% wheat bran, or 5% coarse or fine beet fiber (diets 1–4, Table III). Although weight gains of animals fed the 10% fine and coarse beet fiber diets appeared to be slightly lower than those for animals fed the respective 5 and 7.5% beet fiber diets, the difference was not significant. As expected, feed efficiencies tended to decrease as beet fiber content of the diets increased. At all three levels of dietary beet fiber, the fine fiber diets appeared to be more efficient than the coarse fiber diets.

Total Serum Cholesterol

After three weeks, all animals fed 5% fiber-source diets (diets 1–4) had similar serum cholesterol concentrations (Table IV). However, serum cholesterol was lower in animals fed 10% fine or coarse beet fiber (diets 7 and 8) than in animals in any other dietary groups. By the end of the sixth week, cholesterol levels of animals in all but one of the groups fed a beet fiber diet (7.5% coarse beet fiber) were lower than those in animals fed the cellulose control diet (diet 1). Forsythe et al (1978), who reported no hypocholesterolemic activity for sugar beet fiber, fed rats for only four weeks. Our data indicate that fiber-caused differences in cholesterol might not become apparent in that time. No dose-response effect of beet fiber was noted in this experiment, with serum cholesterol being statistically the same in animals fed 5, 7.5, and 10% beet fiber.

After six weeks, animals fed the 5% wheat bran diet had cholesterol levels intermediate between the cellulose- and beet fiber-fed animals. We did not observe a hypercholesterolemic effect for hard red winter wheat bran, as was reported by Forsythe et al (1978) for white wheat bran of similar particle size. The

TABLE IV
Effects of Coarse and Fine Sugar Beet Fiber and Hard Red Wheat Bran on Rat Serum and Liver Cholesterol Levels[a]

Diet		Total Serum Cholesterol (mg/dl)		Percent High-Density Lipoprotein Cholesterol		Liver Cholesterol (mg/g)
No.	Type	Week 3	Week 6	Week 3	Week 6	
1	5% Cellulose	177 a	179 a	27.9 b	26.0 a	7.24 a
2	5% Wheat bran	156 ab	156 ab	33.5 a	29.6 a	7.47 a
3	5% Fine beet fiber	160 ab	105 c	29.4 ab	32.1 a	7.38 a
4	5% Coarse beet fiber	171 a	119 bc	31.3 ab	32.2 a	7.43 a
5	7.5% Fine beet fiber	166 a	117 bc	36.0 a	33.8 a	6.24 bc
6	7.5% Coarse beet fiber	154 ab	142 ab	35.3 a	29.8 a	6.34 b
7	10% Fine beet fiber	137 bc	112 bc	33.4 ab	34.9 a	5.26 cd
8	10% Coarse beet fiber	122 c	121 bc	32.4 ab	32.5 a	4.59 d

[a] Means in the same column not followed by the same letter are significantly different at $P < 0.05$.

TABLE V
Effects of Coarse and Fine Sugar Beet Fiber and Hard Red Wheat Bran on Rat Serum and Liver Triglyceride Levels[a]

Diet		Serum Triglycerides (mg/dl)		Liver Triglycerides (mg/g)
No.	Type	Week 3	Week 6	
1	5% Cellulose	101.6 a	89.7 a	5.08 a
2	5% Wheat bran	99.5 ab	88.0 a	4.67 a
3	5% Fine beet fiber	75.0 b	71.4 a	4.06 b
4	5% Coarse beet fiber	108.0 a	67.7 a	3.88 b
5	7.5% Fine beet fiber	95.8 ab	78.9 a	3.34 c
6	7.5% Coarse beet fiber	99.5 ab	72.4 a	3.30 c
7	10% Fine beet fiber	76.0 b	78.7 a	3.18 c
8	10% Coarse beet fiber	81.2 b	89.2 a	2.50 d

[a] Means in the same column not followed by the same letter are significantly different at $P < 0.05$.

reason for the conflicting results might lie in the difference in variety of wheat bran tested, since Munoz et al (1979) reported a hypocholesterolemic effect for hard red spring wheat bran but not for soft white wheat. In general, our results corroborate those of other investigators, who have found little or no hypocholesterolemic effect of dietary wheat fiber (Kay and Truswell 1980). Total serum cholesterol levels were more highly correlated with percent soluble dietary fiber ($r = -0.739$) than with percent TDF ($r = -0.256$). The slightly higher concentrations of cholesterol in animals fed the coarse beet fiber than in those fed fine fiber were not statistically significant.

HDL Cholesterol

The percent of HDL cholesterol was significantly higher at the end of week 3 in animals fed wheat bran and some beet fiber diets than in those fed the cellulose-containing diet, diet 1 (Table IV). The same trend appeared at the end of week 6, but the differences then were not significant. Although serum total cholesterol was lower with the 5% beet fiber diets than with the other 5% fiber diets at the end of week 6, the percent of HDL cholesterol was not lower, indicating that the reduction was at the expense of other lipoprotein cholesterol fractions.

Liver Cholesterol

All animals fed 5% fiber (diets 1–4) had similar liver cholesterol concentrations, but increasing levels of either fine or coarse dietary beet fiber resulted in significantly reduced liver cholesterol (Table IV).

Serum Triglycerides

At the end of week 3, serum triglyceride levels were lower in some groups of rats fed beet fiber (5% fine and 10% coarse and fine) than in animals fed the 5% cellulose diet (Table V). However, at the end of week 6, serum triglyceride concentrations were generally lower in all animals, and there were no significant differences among the dietary groups. These data also indicate that three-week feeding periods are insufficient to measure the effects of dietary fiber on blood lipids.

Liver Triglycerides

Both the type and concentration of dietary fiber affected liver triglyceride levels. Rats fed 5% sugar beet fiber had lower triglyceride concentrations than those fed 5% cellulose or wheat bran. As dietary beet fiber concentration increased, liver triglyceride levels decreased. At the 10% level, coarse beet fiber appeared to have a greater effect than fine beet fiber.

Effect of Fiber on Feces Weight and Water-Holding Capacity

Feces wet and dry weights during weeks 3 and 6 were heavier and fecal water-holding capacity was lower for rats fed 5% cellulose diets than for those fed 5% wheat bran; no significant differences were found between the effects of 5% wheat bran and 5% coarse or fine beet fiber (Table VI). Considerable research has been devoted to comparing the bulking properties of cellulose, wheat bran, pectin, and other sources of dietary fiber (Cummings 1982). When Schneeman (1986) reviewed the topic, she listed the following factors as contributing to increased fecal bulk: 1) the presence of undegraded fiber residue, 2) an increase in fecal water, and 3) an increase in fecal cell mass from intestinal fermentation of metabolizable fibers. The present study has shown that higher water-holding capacity was not responsible for increased fecal weights in animals fed cellulose diets; those samples actually had the lowest water-holding capacity. Little increase in bacterial mass should occur with cellulose fiber, since it is not highly utilizable by other than rumen microorganisms. Therefore, the increased feces weight in cellulose-fed animals apparently arose either from the undegraded fiber or from other dietary solids residue.

In general, wet and dry feces weights increased as percent of dietary beet fiber increased. Beet fiber particle size and surface area had no effect on feces weight or water-holding capacity at the 5, 7.5, or 10% level of supplementation. This is in contrast to results reported for wheat bran, in which fine grinding (to 173 μm geometric mean diameter) significantly reduced fecal output because of reduced fecal water (Wrick et al 1983). However, our results are compatible with data from recent studies indicating that water adsorption isotherms are affected less by fiber particle size than by fiber particle type (Cadden 1988).

CONCLUSIONS

Dietary sugar beet fiber was shown to be an effective lowering agent for blood and liver cholesterol and triglycerides. In addition, its water-holding, or "bulking," capacity was nearly the same as that of wheat bran. Grinding to smaller particle size did not destroy those properties. Sugar beet fiber appears to be a potential dietary aid in the treatment of hypercholesterolemia and constipation.

TABLE VI
Effects of Coarse and Fine Sugar Beet Fiber on Fecal Weights and Moisture Contents[a]

Diet		Feces Wet Weight (g)		Feces Dry Weight (g)		Water-Holding Capacity[b]	
No.	Type	Week 3	Week 6	Week 3	Week 6	Week 3	Week 6
1	5% Cellulose	12.9 a	17.2 a	11.4 a	14.0 a	12.5 c	23.4 b
2	5% Wheat bran	10.3 b	12.6 bc	8.0 bc	9.0 cd	26.9 ab	38.9 a
3	5% Fine beet fiber	8.6 b	11.1 c	7.2 c	8.3 d	18.6 bc	33.6 ab
4	5% Coarse beet fiber	9.5 b	11.3 c	7.7 bc	8.9 cd	23.0 ab	26.4 ab
5	7.5% Fine beet fiber	10.2 b	14.5 ab	8.5 bc	11.0 b	18.9 bc	31.6 ab
6	7.5% Coarse beet fiber	9.7 b	14.9 ab	8.1 bc	10.1 bc	18.9 bc	48.2 a
7	10% Fine beet fiber	13.0 a	15.8 a	9.0 b	11.4 b	27.3 a	41.2 a
8	10% Coarse beet fiber	14.5 a	14.9 ab	11.1 a	11.7 b	28.5 a	31.1 ab

[a] Means in the same column not followed by the same letter are significantly different at $P < 0.05$.
[b] Water-holding capacity = (feces wet wt − feces dry wt)/feces dry wt × 100.

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