Nutritional Properties of Coarse and Fine Sugar Beet Fiber and Hard Red Wheat Bran. II. Effects on Calcium and Iron Utilization

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ABSTRACT

This study compared the effects of coarse and fine dietary sugar beet fiber, cellulose, and hard red wheat bran on calcium and iron utilization in rats. At the 5% level of dietary supplementation, all of these fiber sources had similar effects on fecal ash content and percent ash loss in the feces. Losses of both fecal calcium and iron were very high in animals fed the cellulose diets. The effect of 5% wheat bran diets on fecal calcium loss was similar to that of 5% beet fiber (much lower than losses with 5% cellulose), but fecal iron loss with wheat bran diets was nearly as high as with cellulose diets. Femur calcium concentration was lower in animals fed cellulose and wheat bran than in those fed beet fiber at the same level. Data obtained at the end of week 6 were quite different from those obtained at the end of week 3, indicating that care must be taken in drawing conclusions from short-term feeding studies. Correlation coefficients indicated that percent total fecal ash was positively correlated with both total and soluble dietary fiber, but percent fecal calcium and iron losses were not. Strong negative correlations indicated that soluble fiber might actually reduce fecal iron and calcium losses. In addition, femur calcium concentrations and relative femur weights were positively correlated with increasing soluble dietary fiber concentrations.

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Much controversy now surrounds the role of dietary fiber in mineral bioavailability. A considerable amount of evidence indicates that dietary fiber is associated with malabsorption of calcium, iron, and zinc, although the data contain many inconsistencies (Toma and Curtis 1986). Sandberg et al (1982) cited 11 studies suggesting that wheat bran may have an inhibitory effect on mineral absorption, which has been attributed to phytate and/or fiber in the bran. However, the negative effect appears to be different under different conditions and for different minerals (Sandberg et al 1982). Those authors reported that dietary wheat bran containing phytate had little effect on iron, calcium, and magnesium absorption but did decrease zinc absorption. Vahouny et al (1987) reported no indication of iron, calcium, magnesium, or zinc imbalances in rats fed either soluble or insoluble dietary fiber supplements. However, some studies indicate that soluble fibers do not affect mineral balance as much as insoluble fibers (Drews et al 1979, Behall et al 1983). Recently, however, Moak et al (1987) showed that mineral absorption was poorer in people who ate oat bran than in those eating wheat bran.

Although there is some evidence that animals, through the body's homeostatic mechanism, may adapt and compensate for initially reduced mineral absorption levels with high fiber-diets, long-term studies are needed to confirm that this is so (Toma and Curtis 1986).

This study compared the effects of coarse and fine dietary sugar beet fiber, cellulose, and hard red wheat bran on calcium and iron utilization in rats.

MATERIALS AND METHODS

Eight groups of 10 male Wistar rats each were fed casein-based diets containing cellulose, wheat bran, or sugar beet fiber for six weeks as described in Part I, Table I, of this experiment (Klopfenstein 1990). Total dietary fiber (TDF) and soluble dietary fiber (SDF) 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).

Feces collection (during weeks 3 and 6) and blood sampling procedures (at the end of weeks 3 and 6) are also described in Klopfenstein (1990). At the end of the feeding period, animals were sacrificed by placing them in an ether atmosphere. Femurs were obtained and frozen until cleaned and ashed; then they were assayed for calcium by emission spectroscopy. Diets and feces were analyzed gravimetrically for their total ash contents; emission spectroscopy was used to measure their calcium and iron contents after ashing.

Colorimetric methods were used to assay serum for total calcium (cresolphthalein reaction, kit 0150, Stanbio Laboratory, Inc., San Antonio, TX) and iron (ferrozine reaction, kit 0380, Stanbio Laboratory, Inc.).

RESULTS AND DISCUSSION

Effects of Cellulose, Wheat Bran, and Sugar Beet Fiber on Fecal and Femur Ash Contents

Dietary fiber type did not significantly affect total fecal ash content during week 3 or week 6 (diets 1-4, Table I). During both feces collection periods, total grams of ash consumed per day, as well at that excreted daily in the feces, was statistically the same for animals fed 5% cellulose, 5% wheat bran, or 5% coarse or fine beet fiber. When feces ash was considered as percent of mineral intake (percent ash loss in feces), values for diets 1-4 again were not significantly different. Because animals fed the higher-fiber diets consumed more feed, their mineral intakes were higher, and feces ash content was obviously related to mineral intake ($r = 0.770$ during week 3, and $r = 0.860$ during week 6). Dietary fiber concentration also appeared to affect percent of mineral loss, since animals fed 7.5 or 10% beet fiber diets had higher percent losses of ash in feces than those fed the 5% fiber diets.

Animals fed the 5% cellulose diet had the lowest relative femur weight, but the difference was only significant in comparison to the 7.5% fine beet fiber diet. Beet fiber particle size (see Klopfenstein 1990, Table II) had no effect on relative femur weights.

Effects of Fiber on Serum, Fecal, and Femur Calcium

At the end of week 3, serum calcium concentration was higher in animals fed 5% coarse beet fiber than in those fed 5% cellulose or 5% wheat bran (Table II). No differences were found in serum calcium among animals fed the other 5% fiber diets. By the end of the sixth week, serum calcium levels were lower in all animals than they were at week 3, with some being on the lower end of the normal range (9.0-11.2 mg/dl) for male Wistar rats of similar age (Lewi and Marsboom 1981). The decrease between weeks 3 and 6 was less for rats fed 5% cellulose than for those fed any other diet. At week 6 no significant differences were found in serum calcium among rats receiving 5% fiber diets. Dietary beet fiber at the 10% level resulted in decreased serum calcium compared to concentrations in animals fed 5 and 7.5% beet fiber at 3 weeks, but not at 6 weeks.

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TABLE I
Effects of Cellulose, Hard Red Wheat Bran, and Coarse and Fine Beet Fiber on Percent Ash in Feces and Relative Femer Weight[a]

Diet	Mineral Intake[b]		Fecal Ash Content		Percent Ash Loss in Feces[c]		Relative Femur Weight[d]
	Week 3 (g/day)	Week 6 (g/day)	Week 3 (g/day)	Week 6 (g/day)	Week 3	Week 6	
5% Cellulose	0.571 b	0.640 b	0.169 c	0.233 d	29.6 c	36.4 bc	4.28 b
5% Wheat bran	0.623 ab	0.674 ab	0.184 bc	0.230 d	29.5 c	34.1 c	5.56 ab
5% Fine beet fiber	0.625 ab	0.669 ab	0.194 abc	0.246 cd	31.0 bc	36.7 bc	4.96 ab
5% Coarse beet fiber	0.581 b	0.678 ab	0.189 bc	0.249 cd	32.5 abc	36.7 bc	4.40 ab
7.5% Fine beet fiber	0.649 a	0.759 a	0.247 a	0.322 a	38.1 a	42.4 a	6.10 a
7.5% Coarse beet fiber	0.623 ab	0.709 ab	0.212 abc	0.280 bc	34.0 ab	39.5 ab	5.24 ab
10% Fine beet fiber	0.606 ab	0.701 ab	0.212 abc	0.300 ab	35.0 ab	42.8 a	5.21 ab
10% Coarse beet fiber	0.664 a	0.748 a	0.226 ab	0.290 ab	34.0 ab	38.7 ab	5.84 ab

[a] Means in the same column not followed by the same letter are significantly different at $P < 0.05$.
[b] Grams of feed consumed per day during week 3 or week 6 × percent ash in diet.
[c] (Grams of ash in feces/g of ash in feed consumed) × 100.
[d] (Femur wt/body) × 100.

TABLE II
Effects of Cellulose, Hard Red Wheat Bran, and Coarse and Fine Sugar Beet Fiber on Serum and Femur Calcium Levels and Percent Fecal Loss[a]

Diet		Serum Ca (mg/dl)		Fecal Ca Loss[c] (%)		Femur Ca (mg/g)
No.	Type	Week 3	Week 6[b]	Week 3	Week 6[b]	
1	5% Cellulose	10.7 bc	10.2 a	82.2 a	61.0 a*	191 cd
2	5% Wheat bran	10.8 bc	9.4 ab*	48.7 cd	52.2 b	180 d
3	5% Fine beet fiber	11.0 ab	9.8 ab*	45.7 d	49.5 bc	208 ab
4	5% Coarse beet fiber	11.1 a	9.4 ab*	44.3 d	40.8 d	209 ab
5	7.5% Fine beet fiber	11.1 a	9.0 b*	57.2 bcd	44.4 cd	193 bcd
6	7.5% Coarse beet fiber	11.1 a	8.9 b*	56.7 bcd	48.0 bcd	219 a
7	10% Fine beet fiber	10.7 bc	8.9 b*	65.8 abc	42.1 cd*	196 bcd
8	10% Coarse beet fiber	10.5 c	9.2 b*	69.3 ab	41.4 d*	209 abc

[a] Means in the same column not followed by the same letter are significantly diffeent at $P < 0.05$.
[b] Means followed by an asterisk for week 6 are significantly lower than those for week 3 ($P < 0.05$).
[c] (mg Ca in feces/mg Ca in feed consumed) × 100.

Early in the experiment (week 3), percent fecal calcium loss was higher for rats fed the 5% cellulose diet than for those fed wheat bran or sugar beet fiber at the same dietary level (Table II). Later (week 6), the same pattern persisted, although the differences then were smaller. At first (week 3), as percent beet fiber in the diets increased, fecal calcium loss also increased. Apparently, by week 6, the animals had adapted to the higher-fiber diets, because by that time calcium losses with the 7.5 and 10% beet fiber diets were lower than they were at week 3 and were not different from losses with the 5% beet fiber diets. Beet fiber particle size had no significant effect on fecal calcium loss during either sampling period.

Femurs of rats fed cellulose and wheat bran had significantly lower calcium concentrations than those of rats fed the 5% beet fiber diets (Table II). Increasing amounts of beet fiber in the diets did not adversely affect femur calcium concentrations. Femurs of animals fed the coarse beet fiber contained more calcium per gram than those of rats fed the fine beet fiber, with the difference being significant at the 7.5% fiber supplementation level.

TABLE III
Effects of Cellulose, Hard Red Wheat Bran, and Coarse and Fine Sugar Beet Fiber on Serum Iron and Percent Fecal Iron Loss[a]

Diet		Serum Iron (μg/dl)	Fecal Iron Loss[b] (%)	
No.	Type	in Week 6	Week 3	Week 6[c]
1	5% Cellulose	90.8 a	85.8 a	73.3 ab
2	5% Wheat bran	83.3 a	71.1 abc	75.1 a
3	5% Fine beet fiber	72.7 ab	60.6 bc	63.4 bc
4	5% Coarse beet fiber	74.6 ab	61.4 bc	59.3 cd
5	7.5% Fine beet fiber	73.0 ab	69.7 abc	51.1 de
6	7.5% Coarse beet fiber	71.7 ab	53.2 c	42.5 ef
7	10% Fine beet fiber	59.0 b	75.5 ab	45.9 ef*
8	10% Coarse beet fiber	72.1 ab	78.9 ab	39.5 f*

[a] Means in the same column not followed by the same letter are significantly different at $P < 0.05$.
[b] (μg Fe in feces/μg Fe in feed consumed) × 100.
[c] Means followed by an asterisk for fecal iron loss for week 6 are significantly different than those for week 3 ($P < 0.05$).

Effects of Fiber Type and Particle Size on Serum and Fecal Iron Concentrations

Although it appeared that serum total iron concentration was slightly lower in animals fed 5% beet fiber diets than in those fed 5% cellulose or wheat bran, the difference was not significant. However, animals fed 10% fine beet fiber did have serum iron values somewhat below the normal range (70–105 μg/dl; Oser 1965). In general, increasing concentration of dietary beet fiber did not appear to affect serum iron concentrations, except for those animals fed 10% fine beet fiber diets (Table III).

Percent fecal iron loss tended to be higher for animals fed 5% cellulose and wheat bran diets than for those fed 5% sugar beet fiber at both sampling periods. During week 3, percent iron loss tended to increase with increasing percent beet fiber in the diets (with the exception of diet 6), but particle size had no significant effect on percent fecal iron loss. However, by week 6, percent iron loss appeared to decrease as percent beet fiber in the diets increased. Contrary to what was observed for fecal calcium loss, beet fiber particle size did seem to affect iron loss. At every dietary fiber level, percent iron loss tended to be higher with fine than with coarse beet fiber, although the difference was not significant. At the 5% dietary fiber level, iron loss changed little between weeks 3 and 6 for any fiber type. However, at the 7.5 and 10% beet fiber levels, the percent of iron lost in the feces was lower at week 6 than at week 3. It appears that initially

TABLE IV
Correlation Coefficients Showing Statistical Relationship Between Total and Soluble Dietary Fiber Concentrations and Fecal Ash, Calcium, and Iron Losses, Femur Calcium Concentrations, and Relative Femur Weights

	Dietary Fiber[a]	
Variable	**Total**	**Soluble**
Percent ash loss in feces		
Week 3	0.581	0.799*
Week 6	0.752*	0.746*
Percent fecal calcium loss		
Week 3	0.693	−0.336
Week 6	0.162	−0.825*
Percent fecal iron loss		
Week 3	0.401	−0.758*
Week 6	0.162	−0.956*
Femur calcium	0.260	0.539
Relative femur weight	0.270	0.501

[a] * = Significant at $P = 0.05$.

the higher fiber levels increased percent of iron loss, but at week 6, less iron was lost with those diets than with the 5% fiber diets.

CONCLUSIONS

At the 5% level of dietary supplementation, cellulose, hard red wheat bran, and coarse and fine sugar beet fiber all had similar effects on fecal ash content and percent ash loss in the feces. Percent of ash loss in the feces was higher for animals fed 7.5 and 10% beet fiber diets than for those fed 5% fiber diets. However, relative femur weight was lowest for animals fed the 5% cellulose fiber diet, and no significant differences were found in relative femur weights among the other dietary groups.

Losses of both fecal calcium and fecal iron were very high in animals fed the cellulose diets. The effect of 5% wheat bran diets on fecal calcium loss was similar to that of 5% beet fiber (much lower than losses with cellulose), but fecal iron loss with wheat bran was nearly as high as that with cellulose. Femur calcium concentration was lower in animals fed cellulose and wheat bran than in those fed beet fiber at the same dietary level.

It is important to note that although both fecal calcium and iron losses were higher at the higher dietary fiber levels during week 3, that was no longer true during week 6. Also, at the end of the experiment (week 6), relative femur weights and femur calcium concentrations were not lower in animals fed the higher beet fiber diets. These data indicate that care must be taken in drawing conclusions about mineral bioavailability from short-term feeding studies and emphasize the fact that longer-term studies are essential for accurate assessments.

Correlation coefficients showing statistical relationships between TDF and SDF concentrations and percent fecal ash, calcium, and iron losses, femur calcium concentrations, and relative femur weights are shown in Table IV. Percent total fecal ash loss was positively correlated with both TDF and SDF, but percent fecal calcium and iron loss were not. Strong negative correlations for week 6 data indicate that SDF may actually reduce fecal iron ($r = -0.956$) and calcium ($r = -0.825$) losses. In addition, femur calcium concentrations and relative femur weights were positively (although not significantly) correlated with increasing SDF concentrations. Sugar beet fiber is rich in pectic substances (Michel et al 1988), many of which are fermentable by intestinal microflora. It is possible that alteration in intestinal pH caused by fiber fermentation was responsible for the reduced percent of fecal calcium and iron with increasing amounts of SDF in this experiment.

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LITERATURE CITED

BEHALL, K. M., LEE, K., WILSON, A., and PRATHER, E. S. 1983. Effect of purified fibers added to a basic diet on apparent mineral balance of male subjects. Fed. Proc. 42:1063.

DREWS, L. M., KIES, C., and FOX, H. M. 1979. Effect of dietary fiber on copper, zinc, and magnesium utilization in adolescent boys. Am. J. Clin. Nutr. 32:1893.

KLOPFENSTEIN, C. F. 1990. 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. Cereal Chem. 67:538-541.

LEWI, P. J., and MARSBOOM, R. P. 1981. Page 197 in: Toxicology Reference Data—Wistar Rat. Elsevier/North Holland Biomedical Press: New York.

MICHEL, F., THIBAULT, J. F., BARRY, J. L., and de BAYNAST, R. 1988. Preparation and characterization of dietary fiber from sugar beet pulp. J. Sci. Food Agric. 39:77.

MOAK, S., PEARSON, N., and SHIN, K. 1987. The effects of oat and wheat bran fibers on mineral absorption in adult males. Nutr. Rep. Int. 36:1137.

OSER, B. L., ed. 1965. Hawk's Physiological Chemistry, 14th ed. McGraw-Hill:New York.

PROSKY, L., ASP, N. C., SCHWEIZER, T. F., DEVRIES, J. W., and FURDA, I. 1988. Determination of insoluble, soluble and total dietary fiber in foods and food products: Interlaboratory study. J. Off. Anal. Chem. 71:1017.

SANDBERG, A. S., HASSELBLAD, C., HASSELBLAD, K., and HULTON, L. 1982. The effect of wheat bran on the absorption of minerals in the small intestine. Br. J. Nutr. 48:185.

TOM, R. B., and CURTIS, D. J. 1986. Dietary fiber: Effect on mineral availability. Food Technol. Chicago 40:111.

VAHOUNY, G. V., KHALAFI, R., SATCHITHANANDAM, S., WATKINS, D. W., STORY, J. A., CASSIDY, M. N., and KRITCHEVSKY, D. 1987. Dietary fiber supplementation and fecal bile acids, neutral steroids and divalent cations in rats. J. Nutr. 117:2009.

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