Influence of Wheat Bran Particle Size on Vitamins A and E and Cholesterol in Rats

T. S. KAHLON,[1] F. I. CHOW,[1] C. A. HUDSON,[1] F. T. LINDGREN,[2] and A. A. BETSCHART[1]

ABSTRACT

Cereal Chem. 66(2):103–106

Six groups of rats were fed diets that contained either 5% cellulose, 10% cellulose, 22% whole wheat bran, 20.7% coarse (1.29 mm) wheat bran, 21.8% medium (0.75 mm) wheat bran, or 21.4% fine (0.3 mm) wheat bran. A group was sacrificed at time zero. Apparent digestibilities of fat and nitrogen were significantly lower in bran diets compared with cellulose diets. After five weeks, plasma cholesterol was not significantly affected by any of the bran or cellulose diets. Liver values as well as five-week liver storage of retinol equivalents were similar in rats fed bran diets compared with those fed the 5% cellulose diet, which indicates that the bioavailability of vitamin A was not impaired by bran diets. Liver α-tocopherol values as well as five-week storage of vitamin E were significantly lower in rats fed all high-fiber diets compared with cellulose, suggesting impairment of vitamin E bioavailability by high-fiber diets. This impairment of liver storage or total liver vitamin E was significantly greater with whole wheat bran or coarse bran diets than with the high-cellulose diet. These results indicate that 20% wheat bran diets decrease fat and protein digestibility and impair vitamin E bioavailability.

Increased consumption of dietary fiber is being proposed for its potential value in lowering serum cholesterol, preventing colon cancer, and alleviating the symptoms of diabetes and diverticulitis. Some of the effects of increased consumption of dietary fiber have been under investigation, particularly its interference with mineral and vitamin bioavailability. In a 30-day study (Omaye and Chow 1983) with weanling rats, only one out of five cereal products resulted in significantly lower plasma vitamin A than fiber-free controls. Omaye and Chow (1984a) reported significantly increased plasma vitamin E levels with 5 and 20% wheat bran diets compared with the control diet in a five-week study. In other studies with 20% wheat bran diets, plasma vitamin A and E levels were similar to fiber-free control values at the end of eight weeks (Omaye and Chow 1984b) and nine weeks (Omaye and Chow 1986). Mongeau et al (1986) found that 4–20% wheat bran diets had no effect on rat plasma or liver α-tocopherol levels after six weeks.

Altering the particle size of bran has been shown to modify its physiological effects in humans (Heller et al 1980) and to some extent in rats (Cadden 1986, Mongeau and Brassard 1985). Kahlon

[1]Western Regional Research Center, USDA Agricultural Research Service, Albany, CA 94710.

The mention of firm names or trade products does not imply that they are endorsed or recommended by the U.S. Department of Agriculture over other firms or similar products not mentioned.

[2]Lawrence Berkeley Labs, Berkeley, CA 94720.

et al (1986a) found significantly higher liver vitamin A in rats fed coarse or fine wheat bran diets compared with a control diet. Liver vitamin E values were significantly lower in rats fed coarse compared with fine bran diet for six weeks. Plasma total cholesterol was significantly higher in rats fed fine bran compared with control, high-cellulose, or coarse bran after six weeks (Kahlon et al 1986b).

In the previous study (Kahlon et al 1986a), coarse or fine wheat bran treatments used entire bran milled through 2- or 0.5-mm screens, respectively.

The objectives of the current study were to investigate the effect of whole bran or selected wheat bran fractions of distinct particle sizes (1.18–1.40, 0.5–1.0, and 0.250–0.355 mm, using only specific portions of wheat bran) on the bioavailability of vitamins A and E. In addition, the effects of these wheat bran fractions on plasma cholesterol were examined.

MATERIALS AND METHODS

Eighty-four male weanling Sprague-Dawley rats (Bantin and Kingman, Fremont, CA) were individually fed AIN-76A diet (AIN 1980) for seven days. Animals were randomly assigned to seven groups of 12 each. Six groups were fed ad libitum the respective diets for a period of five weeks, and the seventh group was sacrificed to determine basal values.

Diets were formulated to contain 10% total dietary fiber and 5% fat. The control diet contained 5% cellulose (C). Other diets contained 10% cellulose (HC), 22% AACC whole wheat bran (WB), 20.7% coarse (mean particle size 1.29 mm) wheat bran (CB), 21.8% medium (0.75 mm) wheat bran (MB), and 21.4% fine (0.3 mm) wheat bran (FB). Coarse wheat bran was obtained by sieving whole bran through U.S. standard screens on a Ro-Tap shaker, using only that which passed through screen number 14 (1.40 mm) but remained on number 16 (1.18 mm) and discarding the rest of the bran. For medium bran, screens 18 (1.00 mm) and 35 (0.50 mm) were used. Fine bran was obtained by milling whole wheat bran through a 0.5-mm screen in a Wiley mill, then sieving through the Ro-Tap shaker using screens 45 (0.355 mm) and 60 (0.250 mm). Analyzed dietary fiber values for C, HC, WB, CB, MB, and FB diets were 5.4, 10.6, 10.3, 10.4, 10.1, and 10.2%, respectively. Composition of the treatment diets is given in Table I.

Two 72-hr total cumulative fecal collections were made and analyzed for total dietary fiber (Prosky et al 1985) and crude fat (AOAC 1980) content. One seven-day cumulative fecal collection was made for nitrogen determination (Munsinger 1980). The quantitation of fecal data may be less than precise, because no fecal marker was added to the diets during collections.

After five weeks, plasma and total liver samples were analyzed for vitamins A and E by the procedure described by Kahlon et al (1986a). Total plasma cholesterol was determined with a clinical reagent kit (cholesterol reagent 214346, Gilford Systems, Oberlin, OH). In order to correlate the vitamin A and E content of the right lobe of the liver with that of the total liver, the right lobe and the remainder of each liver (total liver minus right lobe) were separated and treated as individual tissues for analysis. Total liver vitamins A and E were obtained by adding the values obtained from the right lobe and remainder of liver. Liver storage of vitamins A and E were obtained (total liver vitamin minus mean basal liver values). Data were statistically analyzed using Duncan's new multiple range test (Steel and Torrie 1960).

RESULTS AND DISCUSSION

Fiber, Fat, and Nitrogen Digestibility

Initial weights of experimental animals four weeks old were similar among treatments (86 ± 1 g). Rats fed the WB diet gained significantly less ($P < 0.05$) weight than those fed the FB or C diets (208 vs. 233 or 241 g).

Bran diets resulted in significantly less ($P < 0.05$) dietary fiber excretion than the HC diet (Table II). Apparent digestibility of the dietary fiber in wheat bran diets was significantly greater than that of the dietary fiber in cellulose diets (43–53 vs. 16–23%).

TABLE I
Composition of Diets (% dry matter)

	Diet					
			Hard Red Wheat Bran[a]			
Ingredient	Control (AIN-76A)	High Cellulose	Whole Bran	Coarse (1.29 mm)	Medium (0.75 mm)	Fine (0.30 mm)
HR[a] Wheat bran	0.0	0.0	22.0	20.7	21.8	21.4
Corn starch	30.0	25.0	14.2	15.4	14.4	14.8
Cellulose	5.0	10.0	0.0	0.0	0.0	0.0
Corn oil	5.0	5.0	3.8	3.9	3.8	3.8
Sucrose	35.0	35.0	35.0	35.0	35.0	35.0
Casein	20.0	20.0	20.0	20.0	20.0	20.0
Mineral mix, AIN-76A[b]	3.5	3.5	3.5	3.5	3.5	3.5
Vitamin mix, AIN-76A[b]	1.0	1.0	1.0	1.0	1.0	1.0
DL-Methionine	0.3	0.3	0.3	0.3	0.3	0.3
Choline bitartrate	0.2	0.2	0.2	0.2	0.2	0.2

[a]AACC hard red reference wheat bran.
[b]American Institute of Nutrition 1980 (vitamin A = 4,000 IU/kg, vitamin E = 50 IU/kg diet).

TABLE II
Apparent Digestibilities of Dietary Fiber, Fat, and Nitrogen[a] in Rats Fed Wheat Bran of Various Particle Sizes

	Dietary Fiber			Fat			Nitrogen		
Treatment	Intake (g/day)	Excretion (g/day)	Apparent Digestibility (%)	Intake (g/day)	Excretion (g/day)	Apparent Digestibility (%)	Intake (g/day)	Excretion (g/day)	Apparent Digestibility (%)
Control (C)	1.2 c	0.9 b	22.9 b	1.1 ab	0.04 b	96.6 a	677 c	30 c	95.6 a
High cellulose (HC)	2.3 a	1.9 a	16.0 b	1.2 a	0.04 b	96.2 a	718 bc	35 c	95.0 a
Whole bran (WB)	2.1 ab	1.0 b	50.1 a	1.0 b	0.09 a	91.0 b	774 ab	62 b	91.8 b
Coarse bran (CB)	2.1 ab	1.0 b	52.8 a	1.0 b	0.09 a	91.9 b	798 a	65 ab	91.7 b
Medium bran (MB)	2.0 b	1.1 b	43.2 a	1.0 b	0.10 a	90.0 b	759 ab	76 a	90.0 b
Fine bran (FB)	2.1 ab	1.1 b	44.0 a	1.1 ab	0.09 a	91.6 b	795 a	73 a	90.8 b
SEM	0.1	0.1	2.7	0.03	0.004	0.3	23	4	0.1

[a]Values for intake and excretion are means of two fecal collections of three days each (dry matter basis), except for nitrogen values which are means of one seven-day collection ($n = 12$). Means with different letters within a column are significantly different ($P < 0.05$).

Rats fed bran diets excreted significantly more ($P < 0.05$) fat and nitrogen than those fed cellulose diets, resulting in significantly lower apparent digestibility values for fat (91.1 vs. 96.4%) and nitrogen (91.1 vs. 95.3%) for bran diets compared with cellulose diets. This small but significant decrease in apparent fat digestibility from bran diets may not be of much physiological importance to the rat, but it may have some potential in terms of human weight reduction with high fiber diets. Diminished N digestibility by wheat bran has been reviewed by Betschart (1982). Wheat bran particle size did not affect N digestibility in this study.

Feeding the WB or CB diets resulted in significantly lower ($P < 0.05$) fasted body and liver weights than the C diet, whereas feeding the MB diet resulted in significantly lower fasted body weight but similar liver weight compared with the C diet (Table III). These data suggest that body and liver weights are not consistently positively correlated.

Plasma Cholesterol

Plasma cholesterol values were not significantly influenced in rats fed treatment diets compared with the control diet (Table III); however, rats fed the FB diet had significantly higher ($P < 0.05$) plasma total cholesterol than rats fed the HC diet. This agrees somewhat with our previous study (Kahlon et al 1986b), in which plasma total cholesterol levels were significantly higher in rats fed fine bran (0.15–0.46 mm) compared with those fed coarse bran (0.19–1.4 mm) or 5 or 10% cellulose diets.

Ranhotra et al (1977) found that diets containing 50% wheat bran of 30-, 50-, or 70-mesh (coarse, medium, and fine, respectively) lowered serum cholesterol when fed to rats for four weeks, the fine mesh bran having the greatest cholesterol-lowering effect. Cadden (1986) found no effect of feeding 20% wheat bran or bran particle size (whole bran vs. bran ground through a 1-mm screen) on serum cholesterol in rats. The results of the present study are in disagreement with Ranhotra et al (1977) but agree with Cadden (1986) and Kahlon et al (1986b); consumption of wheat bran at 20% of the diet did not lower serum cholesterol in rats. In addition, reducing the particle size of wheat bran in the diets to less than 0.5 mm may result in an increase in plasma cholesterol.

Plasma and Liver Vitamins A and E

Results of vitamin A and E analyses of the right lobe or the remainder of the liver (minus right lobe) showed that expressing the results in micrograms per gram from either of these portions of liver did not accurately reflect total liver status of these vitamins, as it failed to account for significant liver weight differences. It was found that liver right lobe had higher concentrations of vitamins A and E than the total liver; a similar observation for vitamin A in liver in humans has been reported by Olson et al (1979). The results for vitamin A and E analyses in this study are reported both in micrograms per gram and total micrograms per liver. The vitamin A and E values expressed in micrograms per gram of liver are confounded by significant differences in liver weights among treatments but are included for purposes of comparison.

Plasma retinol was significantly higher ($P < 0.05$) in rats fed FB compared with those fed the HC diet (Table IV). However, total liver retinol values (μg/liver) were significantly higher in CB- or WB-fed rats compared with those fed control diet. In rats fed bran diets, total liver values of both retinyl palmitate (the primary storage form of retinol in the liver) and total liver retinol equivalents (R Eq = [retinol] + [retinyl palmitate/1.8345]), were similar to those in control-fed rats. In rats fed the CB diet, retinyl palmitate and retinol equivalent values were significantly higher than in rats fed the MB diet. Based on plasma retinol and total liver retinol equivalents, vitamin A bioavailability was not significantly impaired by dietary fiber from whole bran or selected fractions of distinct particle size wheat bran. In our previous report, bioavailability of vitamin A was significantly enhanced by 10% cellulose and 22% wheat bran (2 or 0.5 mm) diets compared with a 5% cellulose control (Kahlon et al 1986a).

Plasma α-tocopherol was significantly lower ($P < 0.05$) only in CB diet-fed rats compared with those fed C diet. Total liver α-tocopherol values (μg/liver) were significantly lower in rats fed any of the high-fiber diets, compared with those fed the control (C) diet. These results differ from those reported by Kahlon et al (1986a), where no significant impairment of vitamin E was observed between high-fiber diets and the control. In this study, rats fed the WB or CB diets had significantly lower total liver α-tocopherol than those fed the HC diet. There were no differences in α-tocopherol bioavailability among whole bran or three distinct particle sizes of wheat bran fed in this study, whereas bran milled through a 2-mm screen resulted in significantly greater vitamin E impairment than bran milled through a 0.5-mm screen (Kahlon et al 1986a).

The data show no consistent relationship between plasma and liver levels of vitamins A and E. This is in agreement with our previous findings (Kahlon et al 1986a) that plasma levels are not a reliable index of the liver status of vitamins A and E.

TABLE III
Fasted Body, Liver Weights, and Plasma Total Cholesterol of Rats Fed Wheat Bran of Various Particle Sizes[a]

Treatment	Body Weight (g)	Liver Weight[b] (g)	Plasma Cholesterol (mg/dl)
Control (C)	308 a	9.8 a	58.4 abc
High cellulose (HC)	297 ab	8.9 ab	50.2 c
Whole bran (WB)	274 c	8.8 b	57.4 bc
Coarse bran (CB)	280 bc	8.7 b	58.0 abc
Medium bran (MB)	286 bc	9.4 ab	57.4 bc
Fine bran (FB)	299 ab	9.6 ab	65.8 ab
SEM	7	0.3	3.3

[a] Data are means of 12 rats per treatment. Means with different letters within a column are significantly different ($P < 0.05$).
[b] Values are wet weights after a 16-hr fast.

TABLE IV
Plasma and Liver Concentration of Vitamins A and E in Rats Fed Wheat Bran of Various Particle Sizes[a]

	Plasma		Liver							
			Retinol		Retinyl Palmitate		Retinol Equivalents[b]		α-Tocopherol	
Treatment	Retinol (μg/ml)	α-Tocopherol (μg/ml)	μg/liver	μg/g[c]	μg/liver	μg/g[c]	μg/liver	μg/g[c]	μg/liver	μg/g[c]
Control (C)	0.31 ab	2.49 a	16 c	1.6 c	1,057 ab	110.5 b	592 ab	61.8 ab	265 a	27.3 a
High cellulose (HC)	0.28 bc	2.11 ab	30 a	3.4 a	998 ab	113.7 ab	574 ab	65.4 ab	214 b	24.2 b
Whole bran (WB)	0.30 ab	2.18 ab	20 b	2.3 ab	1,077 ab	124.6 a	607 ab	70.2 a	182 c	20.8 c
Coarse bran (CB)	0.29 ab	1.98 b	22 ab	2.5 a	1,084 a	126.0 a	612 a	71.2 a	179 c	20.7 c
Medium bran (MB)	0.31 ab	2.05 ab	19 bc	2.0 b	945 b	103.5 b	534 b	58.5 b	198 bc	20.9 c
Fine bran (FB)	0.33 a	2.05 ab	19 bc	2.0 b	1,006 ab	105.9 b	568 ab	59.8 ab	201 bc	20.9 c
SEM	0.01	0.15	1.4	0.2	42.8	6.7	23.7	3.8	9.5	0.8

[a] Values are means of determinations after five weeks on treatment diets ($n = 12$). Means with different superscripts within a column are significantly different ($P < 0.05$).
[b] Retinol equivalents = retinol + retinyl palmitate/1.8345.
[c] Data is confounded by significant differences in liver weights among treatments.

TABLE V
Total Liver Storage of Vitamins A and E Above Basal Level After Five Weeks in Rats Fed Wheat Bran of Various Particle Sizes[a]

Treatment	Vitamin A (Retinol Equivalents)				Vitamin E (α-tocopherol)			
	Intake (μg)	Stored μg/liver	Stored μg/g[b]	Stored Intake (%)	Intake (μg)	Stored μg/liver	Stored μg/g[b]	Stored Intake (%)
Control (C)	888 a	283 ab	28.9 ab	32.2 a	33,646 a	167 a	17.0 a	0.50 a
High cellulose (HC)	882 a	265 ab	29.8 ab	30.4 a	33,389 a	116 b	13.0 b	0.35 b
Whole bran (WB)	821 ab	297 ab	33.8 a	36.2 a	32,558 a	84 c	9.6 c	0.26 bc
Coarse bran (CB)	855 ab	303 a	34.8 a	35.3 a	33,851 a	81 c	9.3 c	0.24 c
Medium bran (MB)	792 b	225 b	23.9 b	28.6 a	31,454 a	100 bc	10.6 c	0.32 bc
Fine bran (FB)	825 ab	258 ab	26.9 ab	31.6 a	32,710 a	103 bc	10.7 c	0.32 bc
SEM	23.5	24.0	3.8	3.0	918	9.5	0.7	0.03

[a] Data are means of 12 rats per treatment. Means followed by different letters within a column are significantly different ($P < 0.05$).
[b] Data is confounded by significant differences in liver weights among treatments.

Liver Storage of Vitamins A and E

Vitamin A intake was significantly lower ($P < 0.05$) in rats fed the MB diet than in those fed the C or HC diets (Table V). Total liver vitamin A storage in rats fed the MB diet was significantly lower than that in rats fed CB diet. However, there were no significant differences in percentage of total vitamin A intake stored in the liver among any of the treatment groups. The data suggest that increased intake of dietary fiber from wheat bran or cellulose did not adversely affect liver storage of vitamin A.

Total liver storage of vitamin E in rats fed any of the high-fiber diets was significantly lower ($P < 0.05$) than in rats fed the control (C) diet. CB- and WB-fed rats also stored significantly less total vitamin E than those fed HC diet. There were no significant differences in vitamin E storage among wheat bran particle sizes. These data suggest that increased consumption of dietary fiber from wheat bran or cellulose compared with the control resulted in reduced bioavailability of vitamin E as measured by liver storage or total liver vitamin E and that whole bran and coarse bran diets impaired the bioavailability of vitamin E to a greater extent than the HC diet.

CONCLUSIONS

The bioavailability of vitamin E, but not vitamin A was impaired by increased consumption of dietary fiber from wheat bran or cellulose. This impairment of vitamin E was even greater with the WB or CB diets than with the cellulose diet containing an equivalent amount of dietary fiber.

In the rat, dietary fiber from wheat bran is considerably more digestible than dietary fiber from cellulose, but apparent digestibility of fat and nitrogen are decreased by increased wheat bran consumption.

Plasma cholesterol was not significantly influenced by wheat bran or cellulose.

LITERATURE CITED

AMERICAN INSTITUTE OF NUTRITION. 1980. Second report of the ad hoc committee on standards for nutritional studies. J. Nutr. 110:1726.

ASSOCIATION OF OFFICIAL ANALYTICAL CHEMISTS. 1980. Methods of Analysis, 13th ed. The Association: Washington, DC.

BETSCHART, A. A. 1982. Protein content and quality of cereal grains and selected cereal foods. Cereal Foods World 27:395.

CADDEN, A.-M. 1986. Effects of particle size and breadmaking on physiological responses of meal-fed rats to AACC wheat bran. J. Food Sci. 51:188.

HELLER, S. N., HACKLER, L. R., RIVERS, J. M., VAN SOEST, P. J., ROE, D. A., LEWIS, B. A., and ROBERTSON, J. 1980. Dietary fiber: The effect of particle size of wheat bran on colonic function in young adult men. Am. J. Clin. Nutr. 33:1734.

KAHLON, T. S., CHOW, F. I., HOEFER, J. L., and BETSCHART, A. A. 1986a. Bioavailability of vitamins A and E as influenced by wheat bran and bran particle size. Cereal Chem. 63:490.

KAHLON, T. S., LINDGREN, F. T., ADAMSON, G. A., and BETSCHART, A. A. 1986b. Influence of wheat bran and bran particle size on plasma cholesterol in rats. (Abstr.) J. Nutr. 116:xxv.

MONGEAU, R., and BRASSARD, R. 1985. Dietary fiber and fecal characteristics in rats: Effects of level and particle size of bran. J. Food Sci. 50:654.

MONGEAU, R., BEHRENS, W. A., MADERE, R., and BRASSARD, R. 1986. Effects of dietary fiber on vitamin E status in rats: Dose-response to wheat bran. Nutr. Res. 6:215.

MUNSINGER, R. 1980. Kjeldahl nitrogen analyzing systems. Cereal Foods World 25:52.

OLSON, J. A., GUNNING, D., and TILTON, R. 1979. The distribution of vitamin A in human liver. Am. J. Clin. Nutr. 32:2500.

OMAYE, S. T., and CHOW, F. I. 1983. High fiber breads and breakfast cereals: Effect on rat growth and selected vitamin bioavailability. Nutr. Rep. Int. 28:295.

OMAYE, S. T., and CHOW, F. I. 1984a. Comparison between meal-eating and nibbling rats fed diets containing hard red spring wheat bran: Bioavailability of vitamins A and E and effects on growth. Cereal Chem. 61:95.

OMAYE, S. T., and CHOW, F. I. 1984b. Effect of hard red spring wheat bran on the bioavailability of lipid-soluble vitamins and growth of rats fed for 56 days. J. Food Sci. 49:504.

OMAYE, S. T., and CHOW, F. I. 1986. Lipid-soluble vitamins in blood and liver of rats fed a diet containing hard red spring wheat bran. J. Food Sci. 51:1001.

PROSKY, L., ASP, N.-G., FURDA, I., DeVRIES, J. W., SCHWEIGER, T. F., and HARLAND, B. 1985. Determination of total dietary fiber in foods and food products: Collaborative study. J. Assoc. Off. Anal. Chem. 68:677.

RANHOTRA, G. S., LOEWE, R. J., and PUYAT, L. V. 1977. Effect of particle size of wheat bran on lipid metabolism in cholesterol-fed rats. J. Food Sci. 42:1587.

STEEL, R. G. D., and TORRIE, J. H. 1960. Page 107 in: Principles and Procedures of Statistics. McGraw-Hill: New York.

[Received May 24, 1988. Accepted November 17, 1988.]