Influence of Dietary Fiber on Bile Acid Metabolism

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ABSTRACT

Fiber, when fed to animals or man, will generally cause increased excretion of bile acids. The level of bile acid excretion appears to be a function of the structure of the fiber. Fiber binds bile acids and bile salts in vitro. The extent of binding is characteristic for each type of fiber and each substrate. Bile acid binding may be one mechanism of the physiological action of fiber.

Fiber is a generic term that includes a number of substances, mostly carbohydrate in nature, that are not digested by man. Figure 1 presents a classification of these substances. As can be seen from Table I, different types of fiber have different structures and can be expected to exert different chemical and physiological effects.

Among the earliest investigations into the effects of fiber on bile acid metabolism were those of Portman (1,2). In one study he compared the effects of laboratory ration and a semipurified diet on bile acid metabolism in rats. When rats were maintained on commercial ration, their cholic acid half-life was 2.00 ± 0.23 days, and they excreted about 36 mg/kg of cholic acid and 75 mg/kg of sterol daily. When switched to a semipurified diet consisting of 20% casein, 8% corn oil and 67.6% starch, cholic acid half-time rose to 3.24 ± 0.53 days, and excretion of cholic acid and sterols fell to 10 and 48 mg/kg/day, respectively. Substitution of sucrose for starch resulted in another drop in steroid excretion. Replacement of about one-third of the sucrose with cellulose reduced cholic acid half-time to 1.44 ± 0.21 days, decreased steroid excretion to 30 mg/kg/day, and increased cholic acid excretion to 23 mg/kg/day. In a second experiment (2), Portman showed that extraction of the lipids from commercial ration did not affect its influence on cholic acid metabolism. He also found that addition of the lipid present in lab ration to a semipurified diet did not affect its inhibition of cholic acid metabolism to any appreciable extent (Table II).

Leveille and Sauberlich (3) fed pectin to rats maintained on 1% cholesterol and found a significant increase in bile acid excretion but none in sterol excretion.

We fed rats diets in which 50% of the calories were from either carbohydrate, protein or fat, and the remaining calories divided evenly between the other two sources of calories. The dietary fiber was either cellulose or alfalfa. Four days before the rats were killed, they were given a single dose of [4-^{14}C] cholesterol, and the radioactivity in serum, liver and feces determined. Rats fed alfalfa excreted more radioactivity, but the increase was mostly in the neutral steroid fraction (4). In another experiment, rats fed a semipurified diet with 1% alfalfa added excreted 37% more acidic steroid and 57% more neutral steroid than did controls

Class	Type			Digestibility
Monosaccharide		Glucose, fructose	Available carbohydrate	+
Oligosaccharide		Sucrose, lactose, maltose		+
Polysaccharide		Starch, dextrins		+
	Plant cell contents	Gums	Dietary fiber	-
		Mucilages		-
		Algae polysaccharides		-
		Pectins		-
		Hemicellulose		-
	cell wall	Cellulose (crude fiber)		-
		Lignin* (crude fiber)		-

*noncarbohydrate

FIG. 1. Dietary fiber.

TABLE I

Chemistry of Dietary Fiber

	Main chain	Side chains
Cellulose	glucose	— — —
Hemicellulose	xylose mannose galactose glucose	arabinose galactose glucuronic acid
Pectin	galacturonic acid	rhamnose arabinose xylose fucose
Lignin	sinapyl alcohol coniferyl alcohol coumaryl alcohol	

TABLE II

Influence of Components of Commercial Diet on Cholic Acid Metabolism in Rats[a]

	Cholic Acid		
Diet	t 1/2 (d)	Pool (mg/kg)	Excretion (mg/kg/day)
Chow (C)	2.0	100	35
Extracted chow[b]	2.2	97	31
Semipurified (SP)[c]	4.2	62	10
SP + C-lipid	2.8	50	12
SP + C-Non Sap.	3.7	64	12

[a]After Portman (2).
[b]Extracted with ethanol. Vitamins and corn oil added to level present in SP.
[c]67.6% sucrose; 20% casein; 8% corn oil; 4% salts.

TABLE III

Adsorption of Bile Acids to Fiber[a]

	Binding at pH 3.9		Binding at pH 8.0	
Fiber Source[b]	Cholic acid	Taurocholic acid	Cholic acid	Taurocholic acid
Barley husk	0.97	1.05	1.05	0.75
Oak husk	0.77	0.38	0.51	0.40
Corn meal	1.10	0.74	1.28	1.25
Apple	1.00	1.14	0.59	0.53
Brussels sprout	1.09	1.33	1.03	1.18
Carrot	0.92	0.81	0.51	0.00
Pear	1.00	0.90	0.59	0.58
Turnip	0.91	0.67	0.31	0.30

[a]After Eastwood and Hamilton (8).
[b]Bran mash = 1.00.

(5). The foregoing show that different types of fiber may have entirely different effects on bile acid excretion.

In a study in which baboons were fed semipurified diets containing different carbohydrates (the fiber was cellulose), we observed (6) that the ratio of biliary primary/secondary bile acids was lower in the test animals than in controls who were fed a diet of bread, fruit and vegetables. Specific activity of biliary cholesterol (after administration of [5-^{3}H]mevalonic acid) was similar in all baboons, but bile acid specific activity was 5-7.5 times higher in the control animals. These findings led us to postulate that in a fiber-free or fiber-poor diet, bile acids are not excreted at a rapid rate, and thus they accumulate, bile acid synthesis is shut off, and cholesterol accumulates in the serum. A reduction in synthesis of new bile acids concomitant with continuing bacterial degradation would reduce the ratio of primary/secondary bile acids (5,6). Kyd and Bouchier (7) reached a

TABLE IV

Relative Binding of Bile Acids and Bile Salts to Four Types of Fiber[a]

Substrate acid	% Binding Alfalfa	Bran	Cellulose	Lignin
Cholic	19.9	10.2	3.0	43.7
Taurocholic	6.9	1.4	1.0	22.1
Glycocholic	11.5	3.8	1.2	22.5
Chenodeoxycholic	24.8	18.2	1.9	23.3
Taurochenodeoxycholic	15.1	9.8	0.0	25.4
Glycochenodeoxycholic	14.9	21.4	0.2	25.2
Deoxycholic	10.4	5.4	0.2	17.4
Taurodeoxycholic	11.4	3.4	0.7	30.9
Glycodeoxycholic	27.8	7.8	4.7	52.6

[a]After Story and Kritchevsky (13).

TABLE V

Effects of Bran on Bile Acid Excretion in Man

Dose gm/day	Duration (wks)	Fecal steroids (% change) Acidic mg/day	Neutral mg/day	Ref.
16[a]	3	+32[a]	---	19
36	3	+40	+36	20
28	3	+40	+36	21
39	3	-2	N.C.	22

[a]130 mg/day increase during second control period.

TABLE VI

Bile Composition in Men Fed Bran[a]

	Control	Bran[b]
Cholate (%)	42.2	42.2
Chenodeoxycholate (%)	30.6	43.9
Deoxycholate (%)	27.1	13.8
P/S[c]	2.7	6.2

[a]After Pomare and Heaton (23).
[b]33 g/day; 6-10 weeks.
[c]Primary/secondary bile acids.

similar conclusion during experiments on cholelithiasis in rabbits.

Bile acids will bind to various types of fiber-rich substances, taurocholic acid to a variety of substances with the results shown in Table III. Birkner and Kern (8) tested binding of glycocholic and chenodeoxycholic acids to various foodstuffs and found differences in binding affinity. Balmer and Zilversmit (9) tested binding of taurocholate to stock diet (1.00) and to ground wheat (0.33), ground corn (0.80), ground oats (0.65) and soybean meal (0.69).

We (10) tested the binding of taurocholate to various foodstuffs and found that 100 mg of curry powder, cloves, parsley or oregano all bound significantly more of this bile salt than did 100 mg of alfalfa.

Other experiments with taurocholate showed that the two substances most frequently used as bulking agents in semipurified diets, cellulose and cellophane, bound very little of this material (11). In a later experiment (12), we tested the binding of cholic, chenodeoxycholic and deoxycholic acids and their taurine and glycine conjugates to alfalfa, bran, cellulose and lignin. Each bile acid or salt was bound to a different extent; i.e., each had a specific affinity for each binding substance (Table IV).

Human studies show that populations on a high fiber diet excrete a greater volume of feces and more bile acids than do populations on low fiber diets (13). Antonis and Bersohn (14) studied the effects of low and high fiber diets in groups whose diets also contained high or low levels of fat. On a high fat diet, level of fiber did not affect bile acid excretion; but when the dietary fat was low, fiber enhanced bile acid excretion. Thus, on the high fat (40 cal %)-high fiber (15 g/day) diet, neutral steroid excretion was increased by 50%, but acidic steroid excretion was unaffected. When the diet contained 15 cal % fat, neutral and acidic steroid excretion were increased by 90% and 36%, respectively.

Pectin has been found to enhance bile acid excretion in man. Kay and Truswell (15) fed nine subjects 15 g of pectin daily for 3 weeks. Their triglyceride levels were not affected, but cholesterol levels fell from 224 to 190 mg/dl. In the subjects fed pectin, excretion of neutral steroids rose by 16% and excretion of bile acids by 40%. Miettinen and Tarpila (16) obtained similar results by feeding subjects 50 g pectin per day for 2 weeks. They found a 57% increase in bile acid excretion and only a 10% increase in neutral steroid excretion.

Bran has been studied as a hypocholesteremic agent and is generally ineffective (17). When fed to human subjects, bran will cause a large increase in fecal bulk. The concentration of steroids in feces (mg/g) is lowered, but because of the increased stool weight, the total steroid excretion is enhanced. Table V summarizes four experiments in which bran (16-39 g) was fed to subjects for 3 weeks. An increase in bile acid excretion was observed. It is interesting that Eastwood et al. (18) observed a large increase in bile acid excretion after their subjects were returned to a control diet. When human subjects are fed bran for 6-10 weeks, the level of biliary cholic acid is unchanged, but chenodeoxycholic acid levels increased by 43% and those of deoxycholic acid decrease accordingly (Table VI). The ratio of primary to secondary bile acids is more than doubled (19).

Metamucil, a hydrophilic colloid, has been found to enhance bile acid excretion in man (20,21). The excretion of bile acids is about three times that seen when cellulose is fed and one-ninth that observed when a bile acid binding resin is administered. At a level of 15 g/day, cellulose gives a slight increase in bile acid excretion (20); when 100 g/day is fed to children who are also ingesting 4 g of cholesterol daily, bile acid excretion is increased by 45% (22). Bagasse (10.5 gm/day) did not affect serum lipid levels, but increased fecal bile acid excretion by 50% while reducing fecal neutral steroids by 10% (23).

In summary, most, but not all, types of fiber increase stool weight. In doing so, they may reduce concentration of fecal bile acids, but increase total excretion of bile acids. The effect on bile acid excretion varies with type of fiber. Fiber binds bile acids and bile salts in vitro. The extent of binding is characteristic for each type of fiber and each substrate. Bile acid binding may be one mechanism by which fiber reduces serum cholesterol levels and increases bile acid excretion.

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