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Fiber, Stool Bulk, and Bile Acid Output: Implications for Colon Cancer Risk[1]

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Dietary fiber has direct effects on stool bulk and bile acid output that may be of relevence in the etiology of colon cancer. Most types of fiber increase the total volume of stool and reduce the concentration of specific substances, including bile acids, that are in contact with the bowel wall. However, fibers differ in their effect on stool bulk, with wheat fiber being a more effective stool bulking agent than fruit and vegetable fibers. In addition, the extent to which a specific fiber reduces bile acid concentration will be modified by its concomitant effects on total fecal sterol excretion. Whereas wheat bran reduces fecal bile acid concentration, pectin, lignin, and oat bran do not. These three fibers significantly increase total bile acid output. Bile acids act as promoters of colonic tumors in mutagenesis assay systems and in various animal models. Human epidemiological studies show a relationship between various dietary variables, including fat and fiber intake, fecal concentration of bile acids, and colon cancer risk.

Fiber consumption is only one of several dietary variables tentatively implicated in the etiology of large bowel cancer. Epidemiological data are suggestive of a protective effect (13, 26), although the relative importance of different fiber types is uncertain (5). Undoubtedly, other dietary factors are operative (1, 6, 11, 23, 32).

A number of mechanisms may be postulated by which fiber may mitigate against colon carcinogenesis (Table 1). These modes include effects on stool bulk and transit time. Dietary fiber contains a range of polysaccharides susceptible to the action of bacterial enzymes. Fermentation of fiber is significant in that modification of the chemical environment of the colon may alter bacterial metabolism of bile acids and other carcinogens and procarcinogens (Fig. 1).

Colonic transit time is reduced by most types of fiber, thus reducing the opportunity for carcinogen formation and action. In addition, through its effect on stool bulk, fiber may lower the concentration of fecal carcinogens, thereby reducing the amount of these substances that comes into contact with the colonic mucosa. Most types of fiber do increase stool bulk and reduce the concentration of specific substances in the colon, including bile acids.

Bile acids act as promoters of colon cancer in mutagenesis assay systems (31) as well as in conventional and germ-free rats (27), whether given orally or given intrarectally (21). A series of animal studies has demonstrated that dietary ma-

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TABLE 1
DIETARY FIBER AND COLON CARCINOGENESIS

Intestinal transit time
Stool bulk and fecal bile acid concentration
Adsorption of metabolically active materials
Intraluminal antioxidant activity
Chemical environment of the colon
Fecal flora and bacterial enzymatic activity

neuvers designed to increase fecal bile acid concentration result in a concomitant increase in the incidence of large bowel tumors (Table 2). Epidemiological studies also show a relationship between fecal concentration of bile acids and colon cancer risk for humans (13) (Table 3).

Fibers differ in their effect on stool bulk, cereal bran being the most effective (17). In a comparison of vegetable and cereal fiber in human volunteers, Stasse-Wolthuis and colleagues demonstrated that the mean increase in stool weight was 4.1 g/g added fiber for wheat bran as compared with 1.9 g/g added fiber for fruit- and vegetable-derived fiber (33). The latter sources of fiber are rich in fermentable polysaccharides, and bacterial fermentation results in loss of the water-holding matrix and, hence, a relative reduction in stool-bulking capacity.

Although effects on stool bulk are important, the extent to which a specific fiber reduces fecal bile acid concentration will be modified by its concomitant effect on total sterol excretion. Whereas wheat bran (17) and a mixture of food-derived dietary fibers (20) reduced fecal bile acid concentration, pectin (16), lignin (29), and oat bran (18) did not, as the latter have significant capacity for bile acid adsorption and act *in vivo* to increase total bile acid output (Table 4).

Dietary fiber may influence colon cancer risk by other mechanisms. Direct adsorption of a number of chemical substances, including carcinogens and co-carcinogens, is possible. *In vitro,* the thermodynamic activity and, hence, the bioavailability of *N*-nitrosodiethylamine was lowered in the presence of lignin (30). Lignin and other fibers also increase the fecal excretion of estrogens. Finally, direct adsorption of bile acids to several fiber types occurs; adsorption is greatest for unconjugated dihydroxy bile acids (15).

It has been postulated that certain types of fiber may act as intraluminal an-

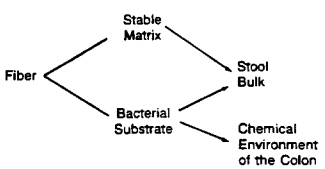

FIG. 1. Effects of dietary fiber on risk factors for colon carcinogenesis.

TABLE 2
BILE ACIDS AND COLON CANCER: ANIMAL STUDIES

	Fecal bile acids	Colorectal cancer	Ref.
Bile diversion to cecum	↑	↑	8
Cholestyramine feeding	↑	↑	24
Rectal BA administration	↑	↑	21
Diversion of fecal stream	↓	↓	14
Elemental diet	↓	↓	7
Dietary fat	↑	↑	22
Meat feeding	↑	↑	34
Pectin	↑	↑	3
Metamucil	↑	↑	28
Bran	↓	↓	10

Note. ↑, increase; ↓, decrease.

tioxidants. Lignin, a universal component of plant cell walls, is believed to be active as a free radical scavenger by virtue of its reducing phenolic groups. This activity is important, since free radical or other oxidative processes involving the production of lipid peroxides may be important in carcinogenesis.

Fiber may have additional effects on bacterial modification of bile acids and other substances in the colon. Fermentable fibers may alter the production of secondary sterols through their effect on colonic pH, since most bacterial enzymes acting on acidic and neutral steroids have pH optima of 6.5 or greater (19). Bacterial modification of fecal steroids apparently is reduced in individuals consuming high-fiber diets or a fiber analog, lactulose (2, 29, 35). Fecal flora might also be expected to be influenced by fiber intake, but this effect has been difficult to demonstrate *in vivo* (25).

In conclusion, clinical and laboratory data suggest a number of mechanisms by which different fiber types may be protective in colon carcinogenesis. Recent epidemiological data support the hypothesis that fiber is protective, although the relative importance of different fiber subtypes remains unclear (4).

TABLE 3
BILE ACIDS AND COLON CANCER: POPULATION STUDIES

Ref.	Group studied	Correlation
Hill *et al.* (12)	9 populations, 4 continents	Good
Wynder and Reddy (36)	Various racial groups (New York)	Good
Crowther *et al.* (9)	3 income groups (Hong Kong)	Good
Reddy *et al.* (26)	Finland and New York	Good
IARC (13)	Finland and Copenhagen	No correlation

TABLE 4
EFFECTS OF DIFFERENT DIETARY FIBERS ON FECAL BILE ACID (FBA) CONCENTRATION

Fiber type	Amount	Species	% FBA	Ref.
Pectin	15 g/day	Human	+8	16
Lignin	8 w/w	Hamster	+100	29
Oat bran	100 g/day	Human	+25	18
Wheat bran	54 g/day	Human	−82	17
Mixed fiber	35 g/day	Human	−41	20

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