perspectives in nutrition

Ischemic heart disease and dietary fiber[1]

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If a dietary factor influences the serum cholesterol level and the incidence of ischemic heart disease (IHD), the evidence may be considered under four headings (1). First, establish dietary intakes in the total population, also in any recognized subgroup; second, relate this data to serum cholesterol level and the incidence of IHD; third, establish correlation with experiments in animals and in man; and fourth, suggest possible metabolic mechanisms. The possible role of dietary fiber under these four headings will be examined in this paper. Shortage of space limits discussion to data from the United States, Europe, and Africa south of the Sahara (2).

Definition of dietary fiber (DF)

Dietary fiber has been defined as the skeletal remains of plant cells that are resistant to hydrolysis by the enzymes of man (3). It is synonymous with the "unavailable carbohydrates" and methods have been suggested by which its constituent substances, cellulose, lignin, pentosans, uronic acids, and so forth can be analyzed (4). Food tables show the crude fiber (CF) content of carbohydrate foods, i.e., the portion that resists extraction by boiling first with 0.255 N sulfuric acid and subsequently with 0.313 N sodium hydroxide (5). CF contains all the lignin and cellulose but most of the pentosans have been extracted by the alkali (4, 6). DF is not the same as CF, although the latter must serve as an approximate measure of the former. It has been suggested that DF may protect against appendicitis (7), cancer of the colon (8), and diverticular disease (2, 9). The latter disease is alleviated by wheat bran, which is rich in fiber.

CF intakes

Data can be derived from two sources, *a*) from retail market food supplies or *b*) intakes recorded during a dietary survey (Table 1).

Almost all Africans south of the Sahara eat natural carbohydrates or lightly processed cereals. In South Africa, corn (maize) is the principal cereal eaten by Bantu and the most popular variety (Impala special) contains 1.4 g CF/100 g (19). In Rhodesia, small hammer mills or hand grinding provide lightly milled cornmeal (20). Millet, the traditional cereal of Africa, is still consumed by many; it contains 4.5 g CF/100 g and even the 76% extraction has 2.0 g CF/100 g (21).

In tropical Africa starchy staples predominate. They contain more moisture than cereals but also a fair amount of fiber, e.g., sweet potatoes, 9.0 g CF/1,000 kcal; tapioca, 7.0 g CF/1,000 kcal; plantains, 2.5 g CF/1,000 kcal (18). Leguminous seeds and groundnuts, rich sources of fiber, are common foods.

Serum cholesterol levels are low and IHD is very uncommon in all indigenous African tribal groups (2, 22). However, the incidence of IHD is now rising in urban areas, especially among Africans who adopt Western patterns of living and diets (23).

Modern Western man, whether in Europe or America, consumes less starchy carbo-

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TABLE 1
Approximate daily crude fiber intakes, g/adult

	Retail market food supplies			
	Cereals	Potatoes and legumes	Fruit and vegetables	Total
USA (10)	0.5[a]	0.9	5.0	6.4
Britain (11)	0.5[a]	1.4	4.5	6.4
	Dietary survey intakes			
Representative groups in Western nations				
Cambridge male students (12)	0.5[a]	(2.2)	(5.3)	8.0
US hospital diet, men (13)	0.5[a]	4.9	3.3	8.7
US men, standard diet (14)	0.9[a]	(4.9)	(4.9)	10.7
South African white male prisoners (15)	1.0	1.0	2.7	4.7
Recognized Western subgroups				
South Italian hospital diet, men (13)	1.1	3.0	14.7	18.8
US men, vegetarian diet (14)	0.9[a]	(6.0)	(17.0)	23.9
Scottish Trappist monks (16)	7.3	(6.0)	(11.7)	25.0
Representative groups in South African Bantu				
Urban men (17)	3.7	(1.0)	(1.0)	5.7
Rural men (17)	13.5	6.0	5.3	24.8

Figures placed within brackets in value columns represent assessment from other known data. Numbers in parentheses in first column are references.

[a] Compromise figure between food tables of the USA and Britain (18). Add fiber 0.5 g if either brown bread, or 1.2 g if wholemeal bread, 100 g/day, are eaten.

hydrates than Africans; modern food has much refined carbohydrate, which contains little CF. In England, bread consumption decreased considerably at the turn of the present century (11) and the fiber content of wheat flour decreased with the modern roller mills introduced from 1880 to 1900. White flour had been desired from time immemorial, even though sieving and other procedures reduced the bran content. It is doubtful if the CF content of flour consumed in England during the last century will ever be known; probably it varied considerably between town and country. From the beginning of the present century, most Englishmen who eat white bread and white flour of 70% extraction (CF a trace (18)) probably consume only 0.5 g CF/day with their starchy cereals. Bran appears to be more effective in alleviating diverticular disease than the plant fiber found in fruit and vegetables (9). Diverticular disease, present in the majority of middle-aged Americans and Europeans, but rarely in Africans (2), was seldom a cause of death in England until the mid-1920's. Diverticular disease mortality increased in frequency until the 1939 wartime rationing provided wheat flour of 85% extraction (0.3 g CF/100 g). After the war, white bread returned to the market in 1953 and diverticular disease mortality rose again. IHD mortality followed the same pattern, becoming recognized in the mid-1920's, rising until the 1939 war, then being somewhat checked, especially in women, and afterwards rising again. Other dietary changes occurred during the period of rationing, such as the reduction of total fat by 20%. The changing mortality rates of IHD and diverticular disease were most marked in women aged 55 to 64 years, as shown in Fig. 1. At autopsy, a good correlation between the severity of diverticular disease and that of atheroma has been reported (24). The frequency of hyperlipidemia and IHD in all countries of Europe and North America is well known and requires no documentation.

In Western society, only two varieties of food have been suggested as ones that reduce hyperlipidemia and protect against IHD. The first variety are cereal products,

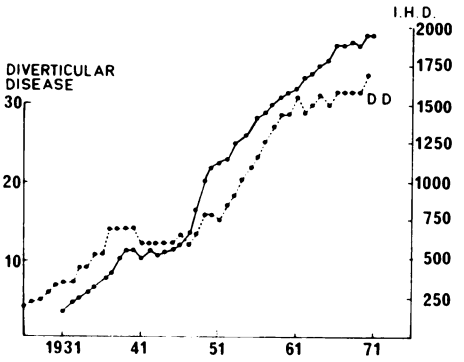

FIG. 1. Death rate per million English women aged 55 to 64 years from ischemic heart disease (IHD) and English women, all ages, from diverticular disease (DD).

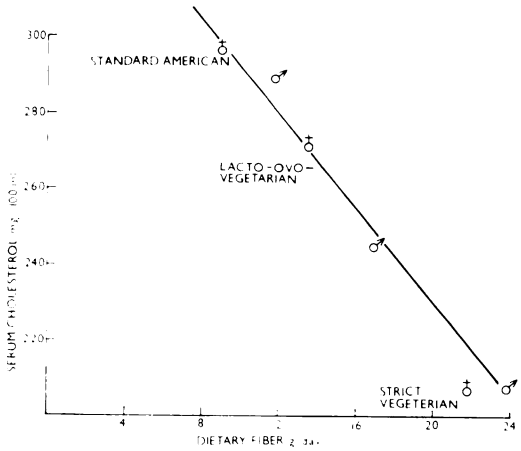

FIG. 2. Inverse relationship between serum cholesterol level and dietary fiber intakes in American men and women.

such as bread if taken in large amounts (25, 26). More information is desirable concerning its CF content, although sometimes it is definitely stated to be whole wheat bread (27). Americans of Italian heritage, even members of the third and fourth generation, such as those living at Roseta, have IHD mortality less than one-half the standard American rate (28). These Italians eat as much fat (38% of calories) as other Americans but they have retained many of their traditional food habits. Italians in Italy consume far more pasta cereal products than any other nation (30 kg/person annually (5)). Pasta is prepared in special mills from hard durum wheat as semolina, different in many respects from white flour (29). Western man seldom eats much rice, but 1,500 to 2,000 kcal were often consumed in the Kempner Diet in the treatment of hypertension. Fats also were much reduced in this therapeutic diet, but the marked fall of serum cholesterol level exceeded that anticipated by the reduction of fat (30). This reduction could be linked to the increased intake of fiber, as rice would provide 3 to 6 g CF/1,000 kcal according to the lightness of the milling (18).

The second variety of foods consumed in large amounts by certain southern European groups are leguminous seeds, all of which have a high CF content. If large amounts are taken, the serum cholesterol level decreases (13, 31–33).

In modern Western society, the question of IHD and hyperlipidemia can be approached in another manner, namely by attempting to identify subgroups with a lower incidence of either of these two aspects of the problem. Those who eat large amounts of fiber-rich wholemeal bread, such as the Trappist monks (27, 32–34), or a diet consisting of vegetables and fruit, such as strict vegetarians (35–37), lacto-ovo-vegetarians (37), and Seventh Day Adventists (38), have a low serum cholesterol and less IHD. Many of these people consume less fat than other members of the same population group, but when a detailed analysis was made of American vegetarians (14, 37), there was a better correlation between the CF intake and serum cholesterol level (Fig. 2) than between the latter and the intake of total fat, saturated fat, or the polysaturated:saturated fat ratio (39).

Experiments in animals and man

The fiber content of starchy foods employed in animal experiments is seldom stated (3), but data from food tables (18) can be inserted, together with published data, such as is now presented on cholesterol-fed rats (40).

In Table 2, it has been assumed that whole ground rice included all the bran (13.5 g CF/100 g) but excluded the husk. If so, whole ground rice produced a greater reduction of serum, hepatic, and aortic cholesterol

TABLE 2

Product	Starch			Cholesterol, mg/100 g		
	Staple, %	Rice bran, %	Fiber, g/100 g	Serum	Liver	Aorta
Rice starch	56	—	0.2	371	48	17
Rice starch	40	16	4.0	255	28	11
Whole ground rice	56	—	2.0	165	21	6
Tapioca starch	56	—	1.5	205	24	8
Tapioca starch	40	16	2.8	130	16	4

than a mixture of rice starch and rice bran. The mixture contained twice as much CF as whole ground rice, but was less effective. This fact, if confirmed in man, may have far-reaching implications in the treatment of hyperlipidemia and prevention of IHD.

Other experiments repeat the same story. Thus, the serum cholesterol level fell in rabbits fed a cholesterol-free diet of ground cereals of Purina Chow (4.5 g CF/100 g), but rose when semi-synthetic diets, containing chemical cellulose in substitution for the natural fiber, were fed (41, 42). Again, ground corn, barley, wheat, and oats, especially the latter, reduced serum cholesterol levels in chicks fed a hypercholesteremic diet of whole eggs (43). Cholesterol-fed rabbits that ate a considerable amount of alfalfa, a leguminous plant rich in fiber, had negligible atherosclerosis compared with others fed a commercial diet (44). In other experiments, wheat straw and peat, both rich in substances present in natural fiber, have protected rabbits against hyperlipidemia and reduced aortic cholesterol (45). Again, rats fed a hypercholesteremic diet were protected by leguminous seeds rich in fiber, such as *Cajanus cajan* (7.0 g CF/100 g) but not by other leguminous seeds containing less fiber, such as *Cicer arietinum* (2.8 g CF/100 g) (46).

In man, few experiments have assessed the the hypocholesteremic effect of cereal products. The bran of oat kernels is thin and pale, and has no detrimental effect on the quality of the milled oat products, so that oatmeal (1.1 g CF/100 g) and rolled oats (0.9 g CF/100 g) are rich sources of fiber as eaten by Western man (29). Twenty-one Dutch male volunteers first ate 300 g of bread for 3 weeks, then 140 g rolled oats were substituted for an isocaloric amount of the bread and thereafter, their mean serum cholesterol levels fell from 258 mg/100 ml to 226 mg/100 ml (47).

The hypocholesteremic effect in man of consuming large amounts of leguminous seeds has often been noted (13, 31, 48). Even when butter (156 g/day) had raised mean serum cholesterol levels in Indian male volunteers, a large amount of Bengal gram (400 g/day) slowly reduced their mean serum cholesterol levels from 206 mg/100 ml to 160 mg/100 ml, and increased their fecal bile acid excretion (49). It should also be noted that whole cereal flours of wheat and corn, containing 14 g CF/day, increased fecal excretion of bile acids in South African white and Bantu prisoners (50).

Suggested metabolic mechanisms

Under certain experimental conditions, lignin sequestrates bile salts (51) and although Western diets contain little lignin, the question of whether natural components of the diet might exert a similar effect has been reviewed (52). The matter has been investigated in cholesterol-fed rats: those fed Purina Chow (4.5 g CF/100 g) excreted more cholic acid, dihydroxycholanic acid, and total bile acids than those fed diets of casein, sucrose, and corn oil (53). In another experiment in rats, fecal excretion of [24-^{14}C] cholic acid, fed orally, was increased in those fed stock pellets (4.7 g CF/100 g), but not in another group of rats fed semi-synthetic diets. This difference occurred to a similar degree both in germfree and conventional groups of rats. It was therefore suggested that some physical interaction had occurred between the bile acids and the diet (54). One other experiment showed that fecal cholic acid excretion was greater in monkeys fed Purina Chow than in those fed

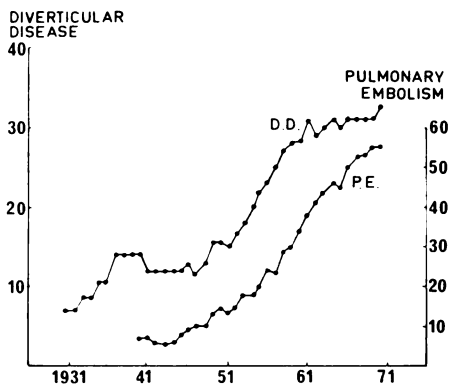

FIG. 3. Death rate per million English women, all ages, from diverticular disease (DD) and pulmonary embolism (PE).

purified diets of sucrose or starch (55). In animals and in man, dietary fiber sequestrates bile acids, decreasing reabsorption in the ileum and reducing hyperlipidemia.

It is not suggested that dietary fiber protects against IHD only by decreasing reabsorption of bile salts. More attention should be directed to the brisk fibrinolysis and rarity of thromboembolic disease in Africans, although the incidence is now rising in urban areas (2, 22). The incidence of fatal pulmonary embolism in England and Wales parallels that of diverticular disease mortality; the former was first registered as a separate category in 1939, it remained almost stationary during the period of wartime rationing, but has been rising rapidly since then (Fig. 3) (56). No mechanisms can be suggested to link dietary fiber with a tendency to thrombosis, but semi-synthetic diets, containing only chemical cellulose, have produced atherosclerosis and thrombosis in cholesterol-fed rats (57).

Summary

Data has been produced to support a hypothesis that high consumption of natural starchy carbohydrates, taken with their full complement of fiber, is protective against hyperlipidemia and IHD. Experiments in animals and man may be interpreted to support a suggestion that dietary fiber decreases the reabsorption of bile salts, increases fecal excretion, and reduces hyperlipidemia.

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