Direct and indirect effects of dietary fibre on plasma lipoproteins in man

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In clinical practice two effects of dietary fibre should be distinguished: A direct, and an indirect effect. An indirect effect of dietary-fibre-rich foods is that they displace from the diet foods high in saturated fat and cholesterol. Thus legumes may displace meat, and whole-wheat bread may displace cookies and cakes. As a result, diets high in fibre-rich foods tend to cause low levels of plasma low-density-lipoprotein (LDL) cholesterol.
Direct effects of fibre are those seen in strictly controlled experiments where intake of all other nutrients is forcibly held constant. Under those conditions we and others observed the following effects:
- Wheat bran fibre does not cause a fall of plasma cholesterol, but may even induce a slight rise.
- Pectin, both isolated or as a constituent of vegetables and fruits, can lower cholesterol by up to 10%.
- The fibre of soy beans present in soy protein concentrate does not have a favourable effect on plasma lipoproteins.
- Addition of fibre-rich foods such as pulses, oats, fruits and vegetables to a conventional lipid-lowering diet caused an extra fall of 10% in plasma cholesterol on top of the 20% fall already caused by the reduction of saturated fats and cholesterol and the increased intake of polyunsaturated fatty acids. The decrease in high-density lipoprotein (HDL) cholesterol caused by the lipid-lowering diet was partly reversed by the addition of plant foods.
- Extreme high-carbohydrate fat-restricted diets cause a fall in HDL as well as in LDL, and the decrease in HDL cannot be completely prevented by the presence of fibre in the diet.
In conclusion, fibre-rich foods have direct and indirect effects that are of benefit in the prevention and treatment of acquired hypercholesterolaemia.

Hypercholesterolaemia is an important cause of premature ischaemic heart disease. Severe hypercholesterolaemia is usually of a genetic origin (1), or arises secondary to metabolic diseases. However, the widespread mild hypercholesterolaemia that is seen so frequently in Northern European countries is largely acquired; it probably arises through an as yet ill-understood interaction between diet and genetic susceptibility. Dietary measures can be very effective in treating this mild hypercholesterolaemia.

In this paper I survey the role that dietary fibre can play in such treatment. The effects of fibre and fibre-rich foods on plasma lipoproteins will be considered under two headings: indirect, and direct effects.

INDIRECT EFFECTS

An increased intake of fibre-rich foods usually leads to a lower fat and cholesterol intake; with controlled diets we have actually had serious problems in reconciling a high fibre intake with a high fat intake (2). In epidemiological surveys (3), too, fibre intake is negatively correlated with the intake of saturated fat and cholesterol (Table 1).

This is to be expected, because plants contain fibre polymers as structural elements and starch as an energy store. Thus, if one increases the uptake of unprocessed plant foods such as beans, cereals, fruits and vegetables then one will increase both fibre intake and the proportion of carbohydrates in the diet, and this will go at the expense of animal foods rich in total and saturated fat and cholesterol.

Table I. Correlation between consumption of dietary fibre and other nutrients in free-living Dutch students (After Niessen et al., ref. 3)

Nutrient	Correlation with fibre consumption
Saturated fat	- 0.44
Cholesterol	- 0.22
Plant protein	+0.70

DIRECT EFFECTS

Direct effects of various fibres can be studied only in carefully controlled experiments where fibre intake is the only variable, and the intake of all other nutrients is forcibly kept constant – a somewhat artificial situation, in view of what was said above.

Under such conditions, different fibre types may perform quite differently.

Wheat bran by itself has shown little or no benefical effect on plasma lipoproteins. Some studies have even shown a slight cholesterol-elevating effect of wheat bran (ref. 4 and Fig. 1). In our own experiment (5) most of this rise was due to low-density lipoproteins.

Pectin and guar have been consistently shown to lower plasma total- and LDL-cholesterol levels. Isolated pectin is too unpalatable to be used as a cholesterol-lowering agent, but pectin-rich fruits and vegetables can produce a similar effect (Fig. 1), and again most of this effect is due to LDL. Although these effects are modest compared with those of dietary lipids, they do support nutritional advice to increase the intake of plant foods.

Soy beans are rich in fibre, like all legumes, and quite appreciable amounts of soybean fibre can be found even in "purified" soy protein preparations (Fig. 2).

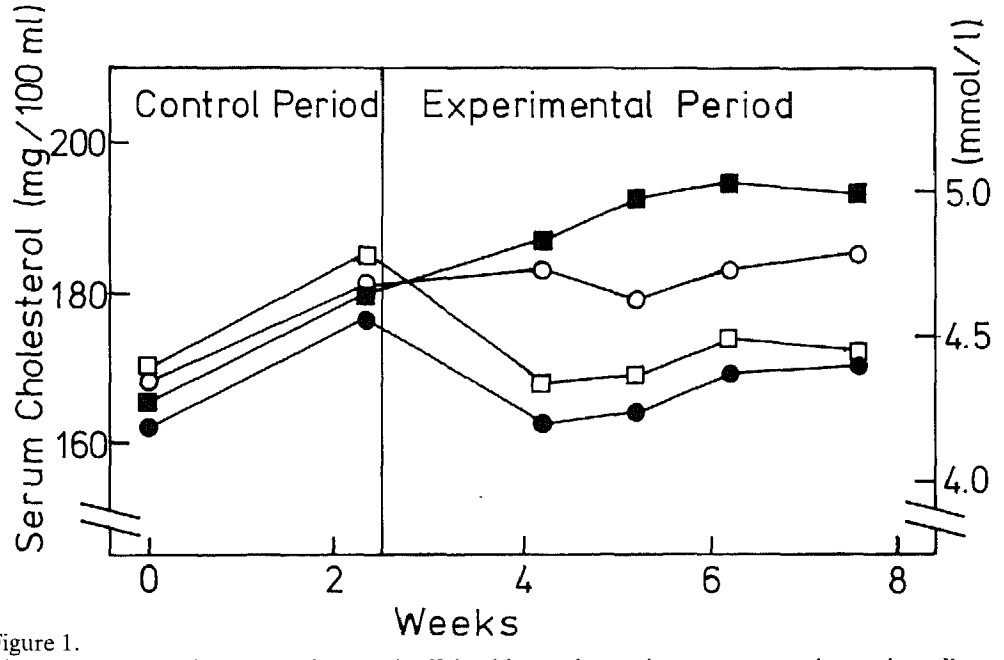

Figure 1.
Time course of total serum cholesterol in 62 healthy student volunteers consuming various diets. All subjects initially received a low-fibre control diet moderately high in total and saturated fat and cholesterol (Control Period). They were then randomly assigned to one of the following diets: o---o, low fibre control diet (as a check against baseline drift; n = 16); ▪---▪, wheat bran added (38 g/day on average, which provided an extra 27 g of fibre; n = 16); □---□, pectin added (on average 9 g/day, providing 6 g of polygalacturonic acid; n = 14); •---•; fruits and vegetables added (providing on average an extra 29 g/day of total fibre, 4.5 g of which was polygalacturonic acid). After Stasse-Wolthuis et al., ref. 5.

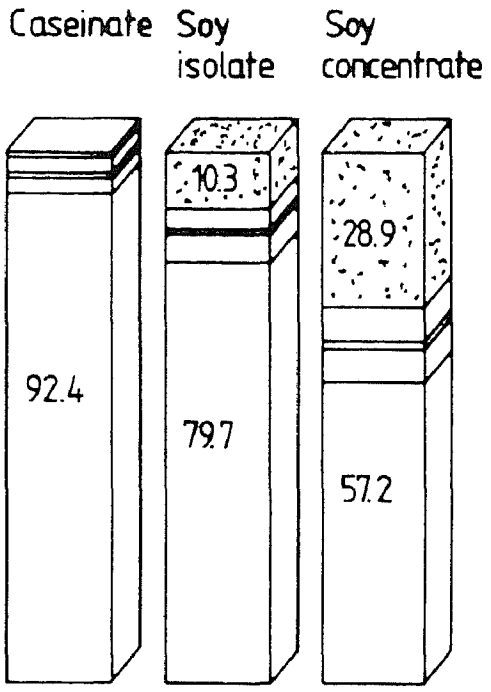

Figure 2.
Composition of the protein preparations in the experiment of Van Raaij et al. (ref. 8 and Fig. 3). Top to bottom: Carbohydrates (lactose in casein; unavailable carbohydrates in the soy preparations); ash; lipid; moisture; protein. Protein was measured by the Kjeldahl method, assuming a protein-to-nitrogen ratio of 6.38 for casein and 5.70 for soy protein.

There are indications that such preparations are very effective in lowering serum LDL-cholesterol in patients with hypercholesterolaemia (6). We ourselves, however, have failed to observe such an effect in normolipaemic volunteers (7,8); indeed, in our hands a fibre-rich soy concentrate produced even higher LDL-cholesterol levels and a lower HDL/LDL ratio than a more highly purified protein isolate (Fig. 3).

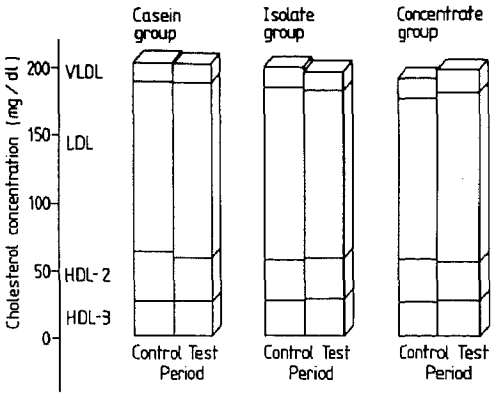

Figure 3.
Effects of casein and soy protein diets on cholesterol concentrations in serum lipoproteins in healthy volunteers (8). During the first 17 days all 57 subjects received the casein diet. During the 28-day test period, 17 subjects continued on the casein diet as a check against baseline drift. Groups of 20 were assigned each to the soy protein isolate and soy concentrate diets. Mean intake of protein was 90 g/d, of which 55 was provided by the various protein preparations. The casein diet provided on average 37, the soy isolate diet 48 and the concentrate diet 69 g of dietary fibre per day. Lipoproteins were separated by density gradient ultracentrifugation using the following density limits: VLDL, <1.006; LDL (plus sinking pre-beta lipoprotein), 1.006-1.075; HDL_2, 1.075-1.125; HDL_3, >1.125.

Table II. Nutrient composition of the reference diet A and the three experimental diets in the study on high-fibre fat modified diets (After Lewis et al., ref. 11)

Nutrient	A	B	C	D
Protein (% of energy)	14	14	14	14
Vegetable protein (% of protein)	34	34	52	49
Fat (% of energy)	40	27	27	40
Linoleic acid (% of energy)	4.6	8.1	8.4	12.4
Polyunsaturates (% of energy)	5.2	8.5	8.7	12.8
P/S ratio	0.27	1.01	1.00	1.01
Cholesterol (mg/2500 kcal)*	617	245	252	245
Available carbohydrates (% of energy)	46	59	59	47
Dietary fibre (g/2500 kcal)*	19	20	55	43
Pectin (g/2500 kcal)* as polygalacturonate	1.2	1.8	6.3	6.5

Alcohol intake was negligible. *Energy intakes varied from 1550 to 4250 kcal/24 h. +Monosaccharides and disaccharides contributed 18-20% energy in all four diets.

Mixed fibre-rich diets made up of a variety of natural high-fibre foods usually have very beneficial effects on blood lipids (9-11). Fig. 4 illustrates this. The cholesterol-lowering impact of the classical low-fibre lipid-lowering diet B is clearly augmented if fibre-rich foods such as oats, legumes, fruits and vegetables are added to it (diets C and D).

Note that the amount and nature of dietary lipid was strictly controlled and was the same for diets B and C (Table II). In this experiment, the fall in HDL_2-cholesterol on diet B, which is commonly seen on fat-restricted diets, appeared to be counteracted by the addition of fibre-rich foods in diet C (11). However, if fat intake is severely restricted HDL will fall, even if the high carbohydrate diet provides large amounts of fibre.

In conclusion, diets containing a variety of fibre-rich foods will help to normalize plasma low density lipoprotein concentrations in people with acquired mild hypercholesterolaemia. However, dietary saturated fatty acids and cholesterol remain the primary food components that influence LDL concentrations, and they should be of prime

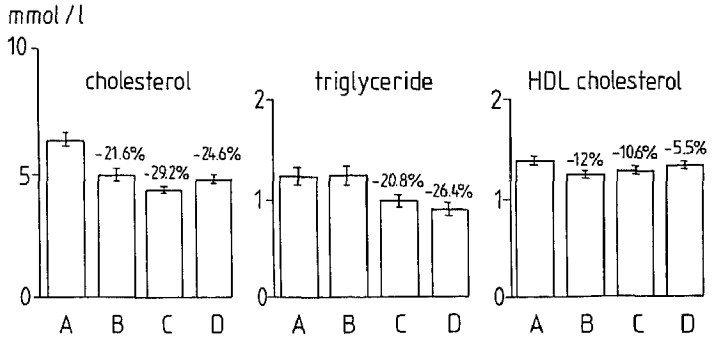

Figure 4.
Effect on plasma lipoproteins of a conventional low-fibre lipid-lowering diet (B) in comparison with a reference low-fibre high-saturated fat diet (A) and two high-fibre fat-modified diets (C and D). Twelve healthy male volunteers each consumed all four diets in random order. Each dietary period lasted five weeks. The composition of the diets is given in Table II. Percentages at the top of columns refer to changes compared to the reference diet A. From Lewis et al., ref. 11.

concern whenever the concentration of atherogenic lipoproteins is elevated.

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