Sugar-beet fibre increases cholesterol and reduces bile acid excretion from the small bowel

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The effect of addition of sugar-beet fibre to the diet on sterol excretion from the small intestine was studied in nine ileostomy subjects. A constant low-fibre diet was given in two 3 d periods with and without 32 g sugar-beet fibre/d in random order. Care was taken to minimize bacterial alteration of the ileostomy contents. The addition of sugar-beet fibre increased net cholesterol excretion by 52 (SE 9)% ($P < 0{\cdot}01$), from 294 (SE 99) to 451 (SE 124) mg/d, and decreased bile acid excretion by 26 (SE 15)% ($P < 0{\cdot}01$), from 764 (SE 118) to 567 (SE 96) mg/d. The increased cholesterol and decreased bile acid excretion found with sugar-beet fibre addition is different from the pattern associated with fibre sources such as pectin and oat fibre. The interaction between dietary fibre and sterol metabolism may be mediated, therefore, by different mechanisms depending on the fibre source.

Dietary fibre: Bile acids: Faecal steroids: Ileostomy

The effect of dietary fibre on lipid metabolism has been a subject of interest for a long time. Dietary fibre from different sources and of different composition has varying effects on serum cholesterol levels (for review, see Truswell & Beynen, 1992). Fibre from most cereal sources, such as wheat bran, does not seem to lower serum cholesterol (Heaton & Pomare, 1974; Jenkins *et al.* 1975; Truswell & Kay, 1975) whereas viscous fibre such as pectin (Jenkins *et al.* 1975; Kay & Truswell, 1977; Miettinen & Tarpila, 1977; Judd & Truswell, 1982) and certain gums (Jenkins *et al.* 1976) have been shown to have distinct hypocholesterolaemic properties. However, it has proved difficult to predict physiological effects from the chemical composition of high-fibre foods (Anderson *et al.* 1990).

The sugar-beet-fibre preparation used in the present study contains 730 g dietary fibre/kg, with a relatively large proportion of pectic substances and hemicellulose (Table 1). This composition would make a hypocholesterolaemic effect probable. In studies of the effects of sugar-beet fibre on serum cholesterol a small effect, about 5%, has been found (Hagander *et al.* 1988, 1989; Israelsson, 1988) and in two recent studies on healthy individuals a 12 and 4·6% decrease in serum cholesterol respectively was found (Lampe *et al.* 1991; Tredger *et al.* 1991). A cholesterol-lowering effect has been found also in animal experiments (Johnson *et al.* 1990).

The cholesterol-lowering mechanism of dietary fibre is often ascribed to increased faecal bile acid excretion, demonstrated repeatedly for pectin and some gums (Kay & Truswell, 1977; Miettinen & Tarpila, 1977; Reddy *et al.* 1980). However, mixed high-fibre diets (Stasse-Wolthuis *et al.* 1979) and psyllium (*Plantago ovata*) husk supplementation (Abraham & Mehta, 1988) produced no change in faecal bile acid excretion but a reduction in serum cholesterol. The addition of beans (*Phaseolus vulgaris*) caused a decrease in bile acid excretion accompanied by a clear hypocholesterolaemic effect (Anderson *et al.* 1984)

Table 1. *Composition of the sugar-beet-fibre preparation Fibrex®*
(Typical proximate analysis (g/kg) provided by Swedish Sugar Co., Arlöv, Sweden)

Dietary fibre, total	730
Pectic substances and hemicellulose	510
Cellulose	180
Lignin	40
Protein (N × 6·25)	100
Sucrose	30–40
Minerals	30–40
Fat	3
Water	100

and bagasse showed an increased bile acid excretion but no effect on serum cholesterol (Walters *et al.* 1975; McLean Baird *et al.* 1977). In these studies cholesterol excretion was not measured.

It seems logical to assume that the mechanisms behind the increased sterol excretion which are suggested to decrease serum cholesterol could be revealed only by careful measurements of bile acid and also of cholesterol excretion. Conventional sterol balance studies have, however, low precision due to variable large bowel transit time and varying bacteriological degradation of sterols (Bosaeus & Andersson, 1990). These problems can be mainly overcome by using the ileostomy model where the ileostomy bags are changed every 2 h and the samples immediately deep-frozen (Sandberg *et al.* 1981). The low day-to-day variation makes such short-term studies feasible with high precision (Tornquist *et al.* 1986).

In the present study we have investigated the effect of adding sugar-beet-fibre to a mixed solid diet on sterol excretion in man. We report here the short-term effects on bile acid and cholesterol excretion in ileostomy subjects.

METHODS

Subjects

Nine subjects (five women, four men) with a mean age of 40 (range 24–64) years and an average weight of 76·4 (range 54·6–113) kg volunteered for the study. The subjects were previously proctocolectomized for ulcerative colitis and had well established conventional ileostomies. The ileostomies functioned properly and the volumes of excreta were within the normal range without the use of drugs. All patients were in good health, without symptoms or signs of small bowel inflammation, ileostomy dysfunction, liver, renal or thyroid disease. Informed consent was obtained from all participants and the study protocol was approved by the Ethical Committee of Sahlgren's Hospital.

Protocol

During two 3 d periods each subject consumed a basal low-fibre diet. In one period 32 g sugar-beet-fibre concentrate (Fibrex®; Swedish Sugar Co., Arlöv, Sweden)/d was added to the diet. Diet periods were selected in random order. The first day of each 3 d period was a run-in day and during the following 2 d ileostomy effluents were collected for analysis (see p. 760).

The sugar-beet-fibre concentrate, Fibrex®, is composed mainly of pectic substances, hemicellulose and cellulose (Table 1). The polysaccharide components of Fibrex® are shown in Table 2. Glucose is derived virtually only from cellulose, which is totally insoluble. Part of the arabinose content and xylose come from the hemicellulose.

Table 2. *The polysaccharide components of the sugar-beet-fibre preparation Fibrex®* (relative distribution of anhydrounits; %)*

Glucose	25·1
Galactose	6·9
Mannose	1·3
Rhamnose	2·5
Xylose	2·0
Arabinose	25·1
Galacturonic acid	31·3
Acetic acid	3·8
Methyl alcohol	1·3
Ferulic acid	0·7

* Swedish Sugar Co., Arlöv, Sweden.

Table 3. *Menu for the basal low-fibre diet*

Breakfast:	Milk/orange juice
	Cheese sandwich
	Coffee/tea
Lunch:	Fillet of plaice/chicken
	Boiled rice
	Tomato, cucumber
	Milk/light beer/water
Snack:	Coffee/tea
	Sponge cake
Dinner:	Fillet of pork
	Boiled rice
	Tomato, cucumber
	Milk/light beer/water
Snack:	Coffee/tea
	Cheese sandwich

Rhamnose is more or less evenly distributed within the galacturonic backbone of the pectin (Rombouts & Thibault, 1986). The rest of the carbohydrates originate from pectin. At least 35% of the pectic substances and hemicellulose (20% of the Fibrex® preparation) are soluble *in vitro* (Asp, 1990). About 50% of the uronic acid carboxyl groups are methylated. Acetyl groups are also attached to the galacturonic acid residues, half of the residues carry one acetyl group at position 2 or 3 (Keenan *et al.* 1985). Feruloyl groups are attached to the end of some of the neutral sugar side-chains.

Diets

The experimental diets were made from conventional food items and care was taken that they should be palatable and acceptable to the subjects. The menu and the mean nutritional values for the basal low-fibre diet are given in Tables 3 and 4. The values for energy, fat and protein were obtained by analysis and the values for carbohydrates were calculated from Swedish Food Composition tables (National Food Administration, 1988).

Before the study records of diet and activity were made for each subject to enable adjustment of the basal diet to each subject's energy needs. Alternatives were available for the lunch dish and the beverages. Adjustment of the energy content was made by varying the servings of bread and rice. To assure compliance to the diet and to check the selected amount of food, a test day with the basal diet preceded the study. The subject's choice was

Table 4. *Diet composition*
(Mean values and standard deviations)

	Basal diet		Basal diet + 32 g Fibrex®*	
	Mean	SD	Mean	SD
Energy (MJ/d)	10·75	2·4	11·05	2·4
Fat (g/d)	78	19	81	14
Protein (g/d)	100	21	100	22
Carbohydrates (g/d)	294	70	302	77
Fibre, total (g/d)	4·3	1·1	27·8	3·6
Fibre from Fibrex® (g/d)	0		23·4	40
Cholesterol (mg/d)	288	40	315	40

* Swedish Sugar Co., Arlöv, Sweden.

then kept constant throughout the study. During one 3 d period 32 g sugar-beet-fibre product/d was added. Sugar-beet fibre was added partly by incorporation in bread and sponge cake and partly as doses divided between the meals, as breakfast cereal or mixed in the rice with the main meals. An average of 15 g Fibrex®/d was incorporated in bread and sponge cake which could be made palatable with a sugar-beet-fibre level of 68 and 49 g/kg respectively.

All food items were purchased in batches before the study and the same batch was used for all subjects. The food was prepared in advance in the metabolic ward kitchen. Individual portions of the meals were stored at $-18°$ and were thawed and heated on the day of consumption. The subjects had all their meals at the metabolic ward and they were carefully instructed not to leave any food or to eat anything but the food served at the metabolic ward. If there were still any leftovers they were collected for analysis.

A duplicate portion of the diet of each patient, from each period, was collected for analysis, homogenized and freeze-dried to constant weight.

Collection of ileostomy contents

Ileostomy contents were collected during the last 2 d in each period. To avoid bacterial degradation the ileostomy bags were changed every 2 h during the day from 07.00 hours until retiring at night. The same bag was kept during the night. Each bag was immediately frozen on dry ice in a portable Dewar vessel (Karlsruher Glasteknik, Karlsruhe, Germany). The bags were weighed, stored at $-20°$ and freeze-dried to constant weight. The contents from each 24 h period (07.00 hours–07.00 hours) were pooled and homogenized for analysis.

Analytical methods

All analyses were made in duplicate. Fat in ileostomy contents was determined according to van der Kamer (1949). Bile acids and neutral steroids in ileostomy contents were analysed as previously described (Bosaeus *et al.* 1986). Briefly, internal standards 5-α-cholestane (Sigma Chemical Co., St Louis, MO, USA) and hyodeoxycholic acid (Serva Feinbiochemika, Heidelberg, Germany) were added, ileostomy excreta were saponified and bile acids deconjugated by alkaline hydrolysis. After extraction and methylation with 2,2-dimethoxypropane, acid and neutral sterols were separated and quantified by GLC using a Varian 3700 system (Varian Instruments, Palo Alto, CA, USA). A 12·5 m SE-54 capillary column was used, with H_2 as the carrier gas and with flame-ionization detection. Cholesterol content of diets was analysed by the same method.

Table 5. *The effect of sugar-beet fibre on ileostomy excretion in subjects given the basal diet with or without a supplement of 32 g Fibrex®†/d‡*

	Basal diet		Basal diet + 32 g Fibrex®	
	Mean	SD	Mean	SD
Wet weight (g/d)	495	56	634	118**
Dry weight (g/d)	44·2	15·3	66·6	14·2**
Fat (g/d)	9·4	5·4	9·6	4·5
Net cholesterol (mg/d)	297	298	451	371**
Chenodeoxycholic acid (mg/d)	294	51	224	120*
Cholic acid (mg/d)	470	209	343	173**
Total bile acid (mg/d)	763	355	566	288**
Net sterol excretion (mg/d)	1060	533	1017	568

Mean values were significantly different from those for the basal diet: * $P < 0{\cdot}02$, ** $P < 0{\cdot}01$.
† Swedish Sugar Co., Arlöv, Sweden.
‡ For details of diets and procedures, see Tables 1–4 and pp. 758–761.

Calculations and statistical methods

Values are given as means with their standard errors. Bile acid and fat excretion are reported as means for each dietary period. The period mean for cholesterol excretion minus dietary cholesterol is expressed as net cholesterol excretion. Mean bile acid plus net cholesterol excretion is termed net sterol excretion, which would be equivalent to the sterol balance concept used in long-term metabolic studies.

Comparisons of values from the two dietary periods were made by Wilcoxon's matched-pairs test. A computer package (MULREG 4·0, Idatron HB, Linköping, Sweden) was used for the actual calculations.

RESULTS

Ileostomy excretion values for the test diets are presented in Table 5. The addition of sugar-beet fibre increased wet weight by 139 (SE 45) g/d (28 (SE 9)%; $P < 0{\cdot}01$). Dry weight increased by 22·4 (SE 1·7) g/d (51 (SE 4)%; $P < 0{\cdot}01$), whereas no significant increase in fat excretion was observed (mean increase 0·2 (SE 0·9) mmol/d; 2 (SE 10)%).

The sugar-beat-fibre-supplemented diet increased net cholesterol excretion by 154 (SE 28) mg/d (52 (SE 9)%; $P < 0{\cdot}01$). Both chenodeoxycholic and cholic acid excretion were reduced, by 70 (SE 23) mg/d (24 (SE 8)%; $P < 0{\cdot}02$) and 127 (SE 31) mg/d (27 (SE 15)%; $P < 0{\cdot}01$) respectively. Only trace amounts of secondary bile acids were detected. Thus, total bile acid excretion was reduced by 197 (SE 51) mg/d (26 (SE 15)%; $P < 0{\cdot}01$).

As the changes in net cholesterol and bile acid excretion opposed one another the total net sterol excretion was not significantly changed, there was a mean decrease of 43 (SE 67) mg/d (4 (SE 6)%).

Wet weight concentration of bile acids decreased by 0·66 (SE 0·15) mg/g on the sugar-beet-fibre diet (42 ± 10%; $P < 0{\cdot}01$). Bile acid concentration on a dry weight basis decreased by 9·18 (SE 1·48) mg/g (52 (SE 8)%; $P < 0{\cdot}01$).

Individual sterol excretion levels and diet responses are shown in Fig. 1. The day-to-day variation was low. The coefficient of variation for small bowel excretion of cholesterol in the present study was 16·6% for the basal diet period and 10·5% for the Fibrex® diet period (Table 6). Two patients complained of bloating during the high-fibre period. Their excretion patterns were the same as those for the rest of the group. None of the patients experienced discomfort during the low-fibre period.

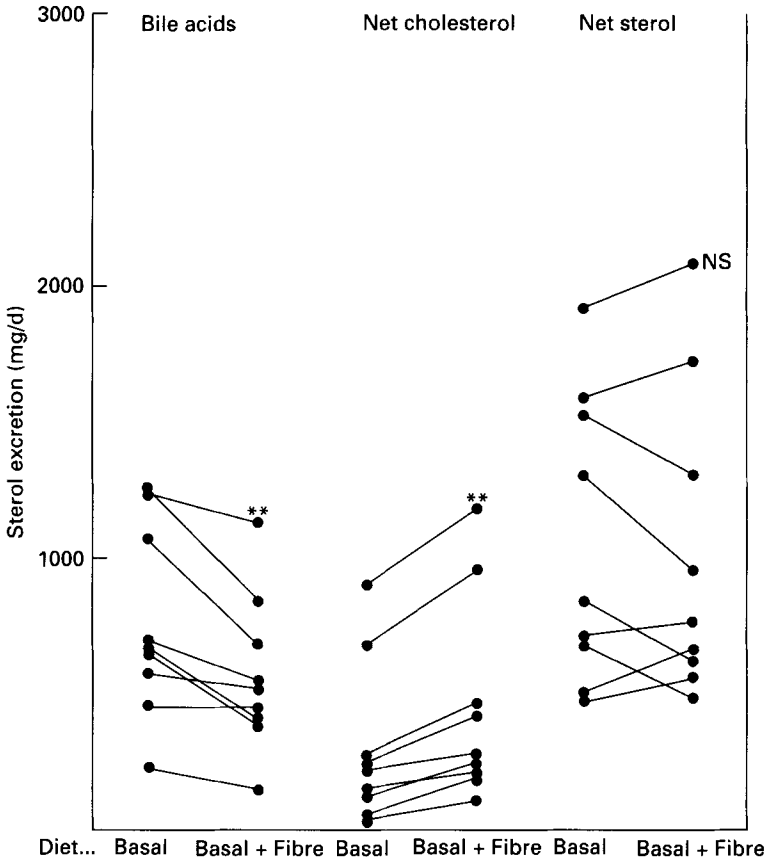

Fig. 1. The effect of sugar-beet fibre on individual sterol excretion in ileostomy subjects given the basal diet with or without 32 g Fibrex® (Swedish Sugar Co., Arlöv, Sweden). For details of diets and procedures, see Tables 1–4 and pp. 758–761. Mean values were significantly different from those for the basal diet: ** $P < 0{\cdot}01$. NS, not significant.

Table 6. *The effect of sugar-beet fibre on the excretion of cholesterol (mg/d) for each individual day of the study in ileostomy subjects given the basal diet with or without a supplement of 32 g Fibrex®*/d†*

	Basal diet		Basal diet + 32 g Fibrex®	
Subject no.	Day 1	Day 2	Day 1	Day 2
1	453	422	539	549
2	468	508	570	578
3	534	508	749	717
4	1024	967	1386	1218
5	1311	938	1604	1398
6	327	327	523	411
7	540	597	745	734
8	429	370	469	638
9	336	443	467	498
Mean	602	564	784	749

* Swedish Sugar Co., Arlöv, Sweden.
† For details of diets and procedures, see Tables 1–4 and pp. 758–761.

DISCUSSION

Sugar-beet fibre, which contains relatively large amounts of the viscous components pectin and hemicellulose (70%), has been shown to have a hypocholesterolaemic effect (Hagander *et al.* 1988, 1989; Israelsson *et al.* 1988; Lampe *et al.* 1991; Tredger *et al.* 1991). Dietary supplementation of the habitual diet of hypercholesterolaemic women with 30 g Fibrex®/d, for 2 weeks (Israelsson *et al.* 1988) and an 8 g Fibrex®/d supplement to the habitual diet of non-insulin-dependent (NIDDM) subjects for 8 weeks (Hagander *et al.* 1988) gave a 4 and 6% decrease in total serum cholesterol respectively. In a later study by the same group of workers (Hagander *et al.* 1989), using NIDDM subjects, the addition of 40 g Fibrex®/d gave an 8% decrease in total serum cholesterol compared with the habitual diet of the subjects, but no decrease when compared with a low-fibre diet. In a recent study on healthy men the addition of 20 g/d of another sugar-beet-fibre product (Betafibre; British Sugar, Peterborough) to the habitual diet gave a 4·6% decrease in cholesterol (Tredger *et al.* 1991). In this study subjects with a high habitual intake of fat had a more pronounced hypocholesterolaemic response to sugar-beet fibre than subjects with a lower habitual intake of fat. The decrease in total serum cholesterol was also accounted for by a decrease in low-density-lipoprotein (LDL)-cholesterol. High-density-lipoprotein (HDL)-cholesterol remained unchanged in these studies (Hagander *et al.* 1988; Tredger *et al.* 1991) or was slightly increased (Israelsson *et al.* 1988; Hagander *et al.* 1989).

Dietary supplementation of a fibre-free liquid formula diet with 30 g/d of yet another sugar-beet-fibre product (American Crystal Sugar Co, Moorhead, MN, USA) in a 3-week experiment in healthy men, gave a 12% decrease in total cholesterol, a 15% decrease in LDL-cholesterol but no change in HDL-cholesterol (Lampe *et al.* 1991).

In the present study we found increased cholesterol excretion and decreased bile acid excretion on addition of 32 g of a sugar-beet preparation Fibrex®/d to a controlled diet with 4·3 g dietary fibre/d, 31% energy (% E) from fat, 17% E from protein and 52% E from carbohydrate. The mean daily intake of cholesterol during the Fibrex® period was 315 mg. Thus, the mean increase in cholesterol excretion of 154 mg/d was about half that amount. Assuming the increased excretion of cholesterol reflects a decreased absorption of cholesterol and that the decreased excretion of bile acids is a secondary effect, the resulting effect on serum cholesterol could well be a small hypocholesterolaemic effect, in accordance with the findings in the previously mentioned studies. The hypocholesterolaemic effect could probably vary depending on which of the effects on sterol metabolism dominates.

Earlier studies with ileostomy subjects have shown that adding 15 g citrus pectin to the basal diet of six subjects induces a significantly increased short-term net excretion of cholesterol of 14%, of bile acids of 35% and also an increased fat excretion (Bosaeus *et al.* 1986). The addition of 15 g citrus pectin/d to the diet has given similar effects in normal individuals (Kay & Truswell, 1977).

The difference in effects between pectic substances in Fibrex® and pectin from other sources may be due to different chemical properties. The main differences between the Fibrex® pectic substances and commercial pectins, e.g. citrus pectin, relates to the solubility, degree of methylation, degree of acetylation and the presence of feruloyl groups. Differences in molecular-weight ranges may exist for the different types of soluble pectic substances but are difficult to ascertain *in vivo*, as deaggregation may occur on dilution. These differences may have implications for the different effects of the Fibrex® pectic substances *v.* the citrus or apple pectin.

Fibrex® contains 510 g pectic substances and hemicellulose/kg, i.e. the subjects were given 16 g pectic substances and hemicellulose/d. The degree of methylation is about 50%. The pectin used in the study of Bosaeus *et al.* (1986) was a citrus pectin (Copenhagen Pectin Factor Ltd, Copenhagen, Denmark) with a degree of methylation of 71–74%. Thus, the

difference in degree of methylation might be one of the explanations for the different effects seen with Fibrex ® and citrus pectin.

The ileostomy model offers a possibility to perform short-term studies on sterol excretion from the small bowel. The present study has shown that the variation in ileal excretion between two consecutive days after 1 d of adaptation is small. Therefore, studies using the ileostomy model can be performed with high precision in 2 d, which is in accordance with our previous experience (Langkilde *et al.* 1990).

Binding and adsorption of bile acids to dietary fibre (Eastwood & Hamilton, 1968; Kritchevsky, 1978) is often claimed to be the mechanism by which dietary fibre alters sterol balance. There is little evidence, however, for a chemical binding between bile acids and dietary fibre (Falk & Nagyvary, 1982). Instead, the impaired absorption of sterols and lipids could be an effect of viscous entrapment due to the physical properties of the dietary fibre (Judd & Truswell, 1982; Ebihara & Schneeman, 1989). NMR spectroscopy studies have also shown that the interactions between pectin and bile acids are probably not due to chemical binding but to viscosity effects (Pfeffer *et al.* 1981). Dietary fibre does not only bind bile acids but also cholesterol and lipids (Eastwood & Mowbray, 1976; Heaton, 1987; Story & Lord, 1987). Thus, due to their physical properties different dietary fibres may have various effects in the small bowel giving different excretion patterns from the small intestine.

The mixed micellar structure is formed by cholesterol, bile acids and phospholipids to facilitate absorption from the gut. Sequestration of all the micellar components, in proportional amounts, have been shown for guar gum (Vahouny *et al.* 1980). Citrus pectin, with known serum cholesterol-lowering effect, has been shown to increase the excretion of both cholesterol, bile acids and fat from the gut (Kay & Truswell, 1977; Bosaeus *et al.* 1986). However, addition of wheat bran, without a significant effect on serum cholesterol, has shown no effects on sterol or fat excretion in ileostomy studies (Bosaeus *et al.* 1986).

Studies in the rat have provided direct evidence that the hypocholesterolaemic potential of certain dietary fibres may be related, at least in part, to direct or indirect effects on the intestinal absorption of dietary and endogenous cholesterol (Vahouny *et al.* 1988). Thus, a similar mechanism could be suggested from the present study of sugar-beet fibre with (1) reduced absorption of cholesterol as the primary effect, resulting in a reduced substance supply to the liver and (2) secondarily a decreased excretion of bile acids, as they are formed by cholesterol in the liver.

Thus, from our ileostomy studies at least three different modes of action for dietary fibre on sterols and fat in the small bowel could be suggested: (1) decreased cholesterol absorption, with a secondary decrease in bile acid excretion, as seen with sugar-beet fibre, (2) interference with the mixed micellar structure, as seen with citrus pectin, (3) no effect on sterol excretion, as seen with wheat fibre. Thus, adding high-fibre foods to a diet may result in different excretion patterns and different effects on blood lipids due to the various effects of fibre products.

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REFERENCES

Abraham, Z. D. & Mehta, T. (1988). Three-week psyllium-husk supplementation: effect on plasma cholesterol concentrations, fecal steroid excretion, and carbohydrate absorption in men. *American Journal of Clinical Nutrition* **47**, 67–74.

Anderson, J. W., Deakins, D. A. & Bridges, S. R. (1990). Soluble fiber. Hypocholesterolemic effects and proposed

mechanisms. In *Dietary Fiber. Chemistry, Physiology and Health Effects*, pp. 339–363 [D. Kritchevsky, C. Bonfield and J. W. Anderson, editors]. New York: Plenum Press.

Anderson, J. W., Story, L., Sieling, B., Lin Chen, W. L., Petro, M. S. & Story, J. (1984). Hypocholesterolemic effects of oat-bran or bean intake for hypercholesterolemic men. *American Journal of Clinical Nutrition* **40**, 1146–1155.

Asp, N.-G. (1990). Delimitation problems in definition and analysis of dietary fiber. In *New Developments in Dietary Fiber*. [I. Furda and J. Brine, editors]. New York: Plenum Press.

Bosaeus, I. & Andersson, H. (1990). The effect of fat quality on intestinal steroid excretion. *Näringsforskning* **34**, 51–55.

Bosaeus, I., Carlsson, N.-G., Sandberg, A.-S. & Andersson, H. (1986). Effects of wheat bran and pectin on bile acid and cholesterol excretion in ileostomy patients. *Human Nutrition* **40C**, 429–440.

Eastwood, M. A. & Hamilton, D. (1968). Studies on the adsorption of bile salts to non-absorbed components of diet. *Biochimica et Biophysica Acta* **152**, 165–173.

Eastwood, M. & Mowbray, L. (1976). The binding of the components of mixed micelle to dietary fiber. *American Journal of Clinical Nutrition* **29**, 1461–1467.

Ebihara, K. & Schneeman, B. (1989). Interaction of bile acids, phospholipids, cholesterol and triglyceride with dietary fibers in the small intestine of rats. *Journal of Nutrition* **119**, 1100–1106.

Falk, J. D. & Nagyvary, J. J. (1982). Exploratory studies of lipid–pectin interactions. *Journal of Nutrition* **112**, 182–188.

Hagander, B., Asp, N.-G., Efendic, S., Nilsson-Ehle, P. & Scherstén, B. (1988). Dietary fiber decreases fasting blood glucose levels and plasma LDL concentration in noninsulin-dependent diabetes mellitus patients. *American Journal of Clinical Nutrition* **47**, 852–858.

Hagander, B., Asp, N.-G., Ekman, R., Nilsson-Ehle, P. & Scherstén, B. (1989). Dietary fibre enrichment, blood pressure, lipoprotein profile and gut hormones in NIDDM patients. *European Journal of Clinical Nutrition* **43**, 35–44.

Heaton, K. W. (1987). Dietary fibre and bile salts. *Scandinavian Journal of Gastroenterology* **22**, Suppl. 129, 172–173.

Heaton, K. W. & Pomare, E. W. (1974). Effect of bran on blood lipids and calcium. Lancet **i**, 49–50.

Israelsson, B., Järnblad, G. & Persson, K. (1988). Serum cholesterol reduced with Fibrex®, a sugar-beet fibre preparation. In *Dietetics in the 90s*, pp. 167–170 [M. F. Moyal, editor]. London: John Libbey Eurotext Ltd.

Jenkins, D. J. A., Leeds, A. R., Newton, C. & Cummings, J. H. (1975). Effect of pectin, guar gum and wheat fibre on serum cholesterol. *Lancet* **i**, 1116–1117.

Jenkins, D. J. A., Leeds, A. R., Slavin, B. & Jepson, E. M. (1976). Guar gum in hyperlipidaemia. *Lancet* **ii**, 1351.

Johnson, I. T., Livesey, G., Gee, J. M., Brown, J. C. & Wortley, G. M. (1990). The biological effects and digestible energy value of a sugar-beet fibre preparation in the rat. *British Journal of Nutrition* **64**, 187–199.

Judd, P. A. & Truswell, A. S. (1982). Comparison of the effects of high- and low-methoxyl pectins on blood and faecal lipids in man. *British Journal of Nutrition* **48**, 451–458.

Kay, R. M. & Truswell, A. S. (1977). Effect of citrus pectin on blood lipids and fecal steroid excretion in man. *American Journal of Clinical Nutrition* **30**, 171–175.

Keenan, M. H. J., Belton, P. S., Matthew, J. A. & Howson, S. J. (1985). A ^{13}C-n.m.r. study of sugar-beet pectin. *Carbohydrate Research* **138**, 168–170.

Kritchevsky, D. (1978). Influence of dietary fiber on bile acid metabolism. *Lipids* **13**, 982–985.

Lampe, J. W., Slavin, J. L., Baglien, K. S., Thompson, W. O., Duane, W. C. & Zavoral, J. H. (1991). Serum lipid and fecal bile acid changes with cereal, vegetable, and sugar-beet fiber feeding. *American Journal of Clinical Nutrition* **53**, 1235–1241.

Langkilde, A. M., Andersson, H., Schweizer, T. F. & Torsdottir, I. (1990). Nutrients excreted in ileostomy effluents after consumption of mixed diets with beans or potatoes. I. Minerals, protein, fat and energy. *European Journal of Clinical Nutrition* **44**, 559–566.

McLean Baird, I., Walters, R. L., Davies, P. S., Hill, M. J., Drasar, B. S. & Southgate, D. A. T. (1977). The effects of two dietary fiber supplements on gastrointestinal transit, stool weight and frequency, and bacterial flora, and fecal bile acids in normal subjects. *Metabolism* **26**, 117–129.

Miettinen, T. A. & Tarpila, S. (1977). Effect of pectin on serum cholesterol, fecal bile acids and biliary lipids in normolipidemic and hyperlipidemic individuals. *Clinica Chimica Acta* **79**, 471–477.

National Food Administration (1988). *Livsmedelstabeller. Swedish Food Composition Tables*. Uppsala: Statens livsmedelsverk.

Pfeffer, P. E., Doner, L. W., Hoagland, P. D. & McDonald, G. G. (1981). Molecular interactions with dietary fiber components. Investigation of the possible association of pectin and bile acids. *Journal of Agricultural and Food Chemistry* **29**, 455–461.

Reddy, B. S., Watanabe, K. & Sheinfil, A. (1980). Effect of dietary wheat bran, alfalfa, pectin and carrageenan on plasma cholesterol and fecal bile acid and neutral sterol excretion in rats. *Journal of Nutrition* **110**, 1247–1254.

Rombouts, F. M. & Thibault, J.-F. (1986). Feruloylated pectic substances from sugar beet pulp. *Carbohydrate Research* **154**, 177–187.

Sandberg, A.-S., Andersson, H., Hallgren, B., Hasselblad, K. & Isaksson, B. (1981). Experimental model for in

vivo determination of dietary fibre and its effect on the absorption of nutrients in the small intestine. *Journal of Nutrition* **45**, 283–294.

Stasse-Wolthuis, M., Hautvast, J. G. A. J., Hermus, R. J. J., Katan, M. B., Bausch, J. E., Rietberg-Brussard, J. H., Velema, J. P., Zondervan, J. H., Eastwood, M. A. & Brydon, W. G. (1979). The effect of a natural high-fiber diet on serum lipids, fecal lipids, and colonic function. *American Journal of Clinical Nutrition* **32**, 1881–1888.

Story, J. A. & Lord, S. L. (1987). Bile salts: In vitro studies with fibre components. *Scandinavian Journal of Gastroenterology* **22**, Suppl. 129, 174–180.

Tornquist, H., Rissanen, A. & Andersson, H. (1986). Balance studies in patients with intestinal resection. How long is enough? *British Journal of Nutrition* **56**, 11–16.

Tredger, J. A., Morgan, L. M., Travis, J. & Marks, V. (1991). The effects of guar gum, sugar beet fibre and wheat bran supplementation on serum lipoprotein levels in normocholesterolaemic volunteers. *Journal of Human Nutrition and Dietetics* **4**, 375–384.

Truswell, A. S. & Beynen, A. C. (1992). Dietary fibre and plasma lipids: Potential for prevention and treatment of hyperlipidemias. In *Dietary Fibre – a Component of Food*, pp. 295–332 [T. F. Schweizer and C. A. Edwards, editors]. London: Springer Verlag Ltd.

Truswell, A. S. & Kay, R. M. (1975). Absence of effect of wheat bran on blood lipids. *Lancet* **i**, 922–923.

Walters, R. L., McLean Baird, I., Davies, P. S., Hill, M. J., Drasar, B. S., Southgate, D. A. T., Green, J. & Morgan, B. (1975). Effects of two types of dietary fibre on faecal steroid and lipid excretion. *British Medical Journal* **2**, 536–538.

Vahouny, G. V., Satchithanandam, S., Chen, I., Tepper, S. A., Kritchevsky, D., Lightfoot, F. G. & Cassidy, M. M. (1988). Dietary fiber and intestinal adaptation: effects on lipid absorption and lymphatic transport in the rat. *American Journal of Clinical Nutrition* **47**, 201–206.

Vahouny, G. V., Tombes, R., Cassidy, M. M., Kritchevsky, D. & Gallo, L. L. (1980). Dietary fibers: V. Binding of bile salts, phospholipids and cholesterol from mixed micelles by bile acid sequestrants and dietary fibers. *Lipids* **15**, 1012–1018.

van der Kamer, J. H., ten Bokkel Huinink, H. & Weyers, H. A. (1949). Rapid method for the determination of fat in feces. *Journal of Biological Chemistry* **177**, 347–355.

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