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Effects of Plant Fiber in Decreasing Plasma Total Cholesterol and Increasing High-Density Lipoprotein Cholesterol (40671)

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Hypercholesterolemia, a common problem in westernized societies, is a major risk factor for ischemic heart disease. Whereas the total serum cholesterol concentration is directly correlated with the prevalence of heart disease, the high-density lipoprotein (HDL) cholesterol concentration is inversely correlated with heart diesase; this suggests that high HDL concentrations may protect from vascular disease (1, 2). Many dietary maneuvers including ingestion of plant fiber lower serum total cholesterol concentrations but the influence of most of these dietary alterations on HDL cholesterol concentrations have not been delineated. Certain water-soluble plant fibers have distinct cholesterol-lowering properties in humans and in experimental animals (3–6). Our preliminary studies (7) suggest that high-fiber diets selectively lower serum total cholesterol concentrations while increasing serum HDL concentrations. Previous studies have demonstrated that fibers such as pectin (3, 4, 8), guar gum (3, 5, 9) and oats (6) lower serum total cholesterol concentrations. In this study, we have examined the effects of fiber-supplemented diets on total and HDL cholesterol concentrations in rats.

Methods. Sprague–Dawley rats were individually housed in stainless-steel cages with raised mesh floors. Rats were randomly divided into five dietary groups of 10 animals each. Food and water were fed *ad libitum.* Food intake and body weights were recorded weekly. Each group of rats were fed one of the five experimental diets containing 46.5% sucrose and 10% plant fibers for 3 weeks (Table I). The five diets were: sucrose diet with 10% cellulose, sucrose–cholesterol diet with 10% cellulose, sucrose–cholesterol–pectin diet with 10% pectin, sucrose–cholesterol–guar gum diet with 10% guar gum, and sucrose–cholesterol–oat-bran diet with 10% oat-bran fiber. The sucrose diet did not contain cholesterol or cholic acid. The other four diets contained 1% cholesterol and 0.2% cholic acid. Cholic acid was added to enhance the hypercholesterolemic effects of cholesterol feeding. At the end of a 3-week period rats were anesthetized with ether and blood was withdrawn by cardiac puncture. After the rats were killed the liver was excised, blotted to remove excess blood, and weighed. Both plasma and liver were stored at −20° until analysis.

The total lipid in liver was extracted by homogenizing the tissue with a 2:1 (v/v) chloroform:methanol mixture and washing the filtered extract with one-fifth volume of 0.9% NaCl (10). The resulting mixture separated into two phases. The weight of total lipid in the chloroform layer was measured by the gravimetric method. A measured aliquot of the chloroform layer was used for cholesterol and triglyceride determinations. The plasma high-density lipoproteins (HDL) were separated by precipitation of low-density lipoproteins (LDL) and very low-density lipoproteins (VLDL) with sodium phosphotungstate-Mg^{2+} (11). A measured aliquot of the supernatant was used for HDL cholesterol determination. Liver and plasma cholesterol was measured by the method of Franey and Amador (12). Liver triglycerides were estimated colorimetrically by the Dade method (13). Plasma triglycerides were measured by the method of Levy (14).

Data were analyzed by using one way analysis of variance. When significant differences were found, Duncan's multiple range test was applied to determine which mean values were significantly different (15).

Results. Initial body weights, weight gains, and food intakes were similar among the rats fed the five experimental diets (Table II).

As expected, plasma total cholesterol, liver total lipid, and liver cholesterol concentrations were significantly higher in cholesterol-fed rats than in rats fed cholesterol-free diets.

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TABLE I. COMPOSITION OF DIETS, g/100 g

	Sucrose–Cellulose	Sucrose–Cholesterol cellulose	Sucrose–Cholesterol pectin[a]	Sucrose–Cholesterol guar gum	Sucrose–Cholesterol oat bran[b]
Carbohydrate, Total	63.1	62.5	62.5	62.5	62.5
Sucrose	46.5	46.5	46.5	46.5	46.5
Starch	16.6	16	16	16	16
Protein, Total	15.6	15	15	15	15
Casein	15.6	15	15	15	7
Oat bran[b]	—	—	—	—	8
DL-Methionine	0.3	0.3	0.3	0.3	0.3
Fat, Total	6	6	6	6	6
Cotton seed oil[c]	6	6	6	6	3.5
Oat bran[b]	—	—	—	—	2.5
Cholesterol	—	1	1	1	1
Cholic acid	—	0.2	0.2	0.2	0.2
Vitamin mixture[d]	1	1	1	1	1
Salt mixture[e]	4	4	4	4	4
Plant fiber, Total	10	10	10	10	10
Cellulose	10	10	—	—	—
Pectin	—	—	10	—	—
Guar gum	—	—	—	10	—
Oat bran[b]	—	—	—	—	10

[a] Pectin (ICN Nutrition Biochemicals, Cleveland, Ohio), molecular weight 150,000–300,000, methylation 8.2%, viscosity 6.2%.

[b] Sucrose–cholesterol–oat bran diet contained 36.5% oat bran (The Quaker Oats Company, Barrington, Ill.). Oat bran contained: protein 22.1%, fat 6.9%(20.2% saturated, 34.8% monounsaturated, and 40.6% polyunsaturated fatty acids), and fiber 27.6%.

[c] Cotton seed oil provided 26.1% saturated, 18.9% monounsaturated, and 50.7% polyunsaturated fatty acid.

[d] Vitamin Diet Fortification Mixture, ICN Nutritional Biochemicals, Cleveland, Ohio.

[e] USP XVII salt mixture (ICN Nutritional Biochemicals, Cleveland, Ohio) supplemented with zinc sulfate 0.081%.

TABLE II. EFFECTS OF FIBER-SUPPLEMENTED DIET ON BODY WEIGHT, FOOD INTAKE, AND PLASMA AND LIVER LIPID LEVELS IN CHOLESTEROL-FED RATS[a]

	Sucrose–Cellulose	Sucrose–Cholesterol cellulose	Sucrose–Cholesterol pectin	Sucrose–Cholesterol guar gum	Sucrose–Cholesterol oat bran
Initial body weight (g)	284 ± 15	292 ± 19	294 ± 14	292 ± 19	295 ± 10
Final body weight (g)	330 ± 22	354 ± 22	334 ± 23	340 ± 24	354 ± 19
Food intake (g/day)	17 ± 1	18 ± 1	17 ± 2	16 ± 2	18 ± 2
Plasma total cholesterol (mg/100 ml)	74 ± 11^{w}	133 ± 13^{x}	84 ± 11^{w}	105 ± 28^{x}	113 ± 8^{x}
Plasma HDL[b] cholesterol (mg/100 ml)	33.8 ± 4.6w	18.4 ± 5.2^{x}	25.8 ± 7.4^{y}	31.0 ± 3.1^{wy}	25.3 ± 5.0^{y}
Plasma triglyceride (mg/100 ml)	107 ± 23^{wx}	126 ± 48^{w}	59 ± 14^{x}	62 ± 23^{x}	86 ± 25^{xy}
Liver total lipid (mg/g)	33.4 ± 3.6^{w}	135 ± 24^{x}	56 ± 16^{y}	68 ± 26^{y}	93 ± 28^{z}
Liver triglyceride (mg/g)	8.2 ± 2.1^{w}	43.2 ± 10.8^{x}	14.8 ± 4.1^{w}	24.4 ± 12.4^{y}	34.2 ± 11.8^{z}
Liver cholesterol (mg/g)	3.5 ± 1.3^{wz}	51.1 ± 14.9^{x}	13.5 ±7.3^{wz}	22.9 ± 14.0^{yz}	27.1 ± 15.3^{y}

[a] Mean ± SD for 9 to 10 rats. Means in the same line with different superscript letters differ significanly ($P < 0.05$).

[b] High-density lipoproteins.

HDL cholesterol levels were significantly lower in rats fed diets containing cholesterol than those in rats that did not receive cholesterol; this has been reported previously (16).

The cholesterol-fed rats that received pectin, guar gum, or oat bran had significantly lower plasma total cholesterol concentrations than those rats that received cellulose; the lowest concentrations were observed in the pectin-treated group. On the other hand, plasma HDL cholesterol concentrations were significantly higher in the cholesterol-fed rats receiving pectin, guar gum, or oat bran than in those rats receiving cellulose. The ratios of total cholesterol: HDL cholesterol for the cholesterol-fed rats treated with pectin, guar gum, and oat bran, ranging from 3.3 to 4.5, were significantly lower than the ratio for

those rats treated with cellulose, 7.3 ($P < 0.05$).

Plasma triglyceride concentrations for cholesterol-fed rats that received pectin, guar gum, or oat bran were significantly lower than those of cholesterol-fed rats that received cellulose. These concentrations were similar among the three groups treated with pectin, guar gum, and oat bran.

Concentrations of liver total lipid, liver triglyceride, and liver cholesterol were significantly lower for cholesterol-fed rats that received pectin, guar gum, and oat bran than concentrations for rats that received cellulose. As noted for plasma total cholesterol, the pectin group had lower concentrations for all three liver lipids than did the other cholesterol-treated groups.

Discussion. Pectin, guar gum, or oat-bran administration attenuate the accumulation of cholesterol in plasma and liver of cholesterol-fed rats (Table II). Similar observations have been reported previously when pectin (4), guar gum (9), or oats (6) were added to the diet of cholesterol-fed rats. Our observations are of interest because these three plant fibers were accompanied by higher plasma HDL cholesterol values than observed in cellulose-fed rats. Consequently, rats fed pectin, guar gum, or oat bran had significantly lower plasma total cholesterol: HDL cholesterol ratios than the cellulose-fed rats.

Many studies (see Ref. (7)) have documented that plant-fiber feeding is associated with reductions in serum cholesterol concentrations in humans and in animals. However, most studies (see Ref. (7)) have failed to demonstrate an effect of plant-fiber feeding on serum triglyceride concentrations. Under the experimental conditions that we used, a significant reduction in plasma triglycerides was observed in rats fed pectin, guar gum, or oat bran; liver triglyceride concentrations also were significantly lower in rats fed these three fibers than in cellulose-fed rats. When persons with diabetes are fed high-fiber diets containing a variety of plant fibers from natural foods, we have observed a significant reduction in serum triglyceride concentrations (7, 17). Further studies are required to delineate the effects of plant fiber on serum triglyceride concentrations.

Water-soluble plant fibers such as pectin and guar gum appear to have greater cholesterol-lowering properties than do water-insoluble fibers such as cellulose or bagasse (3). Oat bran was selected for these studies because approximately one-third of the plant fiber of oat bran is the water-soluble oat gum (18). These water-soluble fibers may lower serum cholesterol concentration by increasing fecal loss of bile acids (4) or by other mechanisms (7). The physiologic processes by which the soluble fibers selectively lower serum total cholesterol values but increase the HDL cholesterol values have not been examined. Durrington and colleagues (8) observed that the reduction in total serum cholesterol when normal subjects were fed pectin for a 3-week period was largely related to a reduction in LDL-cholesterol concentrations.

Therapeutic maneuvers which selectively lower total or LDL-cholesterol levels while increasing HDL-cholesterol levels will be extremely important in the management of hypercholesterolemia. These therapeutic measures may also be indicated for other patients at high risk for coronary artery disease. High-density lipoproteins (HDLs) appear to exert an antiatherogenic effect in humans (1, 2). Recent studies have reported a significant negative correlation between HDL cholesterol and ischemic heart disease (1). HDLs bind the cholesterol released from peripheral tissues such as blood vessels and, also, transport cholesterol to the liver for catabolism (1). A reduction in plasma HDLs may impair the normal clearance of cholesterol from arterial walls and thereby accelerate the development of atherosclerosis (1). *In vitro* studies demonstrate that HDLs promote the elimination of cholesterol from atherosclerotic arterial tissues (19). HDLs may also prevent low-density lipoproteins (LDLs) from entering endothelial cells (20). Enger and colleagues (21) have postulated that alterations in the molar ratio of HDLs to LDLs may disturb the balance between the uptake of cholesterol by arterial wall and its clearance from the arterial wall. Low concentrations of HDLs permit the uptake of LDLs and the release of cholesterol into tissues. Higher concentrations of HDLs reduce the uptake of LDLs and the internalization of cholesterol.

In the light of recent studies suggesting that high concentrations of HDLs exert an an-

tiatherogenic effect, our findings that soluble fibers raise the concentrations of plasma HDL cholesterol while decreasing the plasma total cholesterol concentration in cholesterol-fed animals suggest that soluble plant fibers may be beneficial in the dietary management of hypercholesterolemia.

Summary. Cholesterol-fed rats which received diets supplemented with 10% pectin, guar gum, or oat bran fiber showed a reduced accumulation of cholesterol and triglyceride in both plasma and the liver. In contrast, an increase in the plasma high-density lipoprotein cholesterol levels of these same rats was noted. This study indicates that certain plant fibers selectively lower plasma total cholesterol while raising high-density lipoprotein cholesterol levels.

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