Plasma lipid changes after supplementation with β-glucan fiber from yeast[1–4]

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ABSTRACT
Background: Dietary fiber has been shown to improve blood lipids.
Objective: The purpose of this study was to evaluate the effect on serum lipids of a yeast-derived β-glucan fiber in 15 free-living, obese, hypercholesterolemic men.
Design: After a 3-wk period in which subjects ate their usual diet, 15 g fiber/d was added to the diet for 8 wk and then stopped for 4 wk. Plasma lipids were measured weekly during baseline and at week 7 and 8 of fiber consumption, and again at week 12.
Results: Compared with baseline, fiber consumption significantly reduced plasma total cholesterol (by 8% at week 7 and 6% at week 8; $P < 0.05$ using Bonferroni correction); week 12 values did not differ from baseline. No significant differences were noted between baseline LDL cholesterol and values at weeks 7, 8, or 12 when comparing individual groups by using Bonferroni correction, even though the overall one-way analysis of variance with repeated measures was highly significant ($P < 0.001$). LDL-cholesterol concentrations did decline by 8% at week 8 compared with baseline. There was a significant effect of diet on plasma HDL-cholesterol concentrations ($P < 0.005$ by one-way ANOVA with repeated measures). However, a group difference was observed only between baseline and week 12 (16% increase; $P < 0.05$ by Bonferroni correction). Triacylglycerol concentrations did not change.
Conclusions: The yeast-derived β-glucan fiber significantly lowered total cholesterol concentrations and was well tolerated; HDL-cholesterol concentrations rose, but only 4 wk after the fiber was stopped. *Am J Clin Nutr* 1999;70:208–12.

KEY WORDS β-glucan, dietary fiber, oat fiber, serum cholesterol, low-density-lipoprotein cholesterol, high-density-lipoprotein cholesterol, HDL cholesterol, LDL cholesterol

INTRODUCTION

Each year some 500 000 people die of heart disease in the United States (1). The incidence of new cases is ≈1.1 million each year. The link between elevated plasma LDL-cholesterol concentrations and the risk of developing coronary artery disease has been clearly established (2). Cholesterol-lowering medications are reserved for patients who have not reduced their cholesterol concentrations sufficiently with dietary management and exercise, have already had an infarction or stroke, or do not meet the American Heart Association guidelines for acceptable serum lipid concentrations (3). The National Cholesterol Education Program (NCEP; 3) recommends that most patients with abnormal serum lipid profiles follow the Step I diet plan. The dietary modifications involved include reducing total fat intake to <30% of total energy intake, total saturated fat to <10% of total energy intake, and dietary cholesterol to <300 mg/d. If serum total cholesterol concentrations are not then reduced to values <6.2 mmol/L (240 mg/dL), then the stricter Step II diet should be followed. This diet plan further restricts saturated fat consumption to <7% of total energy and dietary cholesterol to <200 mg/d (1).

Not included in NCEP guidelines are specific recommendations about dietary fiber, although reports indicate that the addition of certain fibers to the diet reduces total cholesterol concentration (4). Recently, the Food and Drug Administration allowed that claim to be made for products containing ≥0.75 g β-glucan from oat products (5). The decision was based on a meta-analysis of numerous reports of studies in hypercholesterolemic patients consuming oat products (6). Patients in these studies achieved reductions in total cholesterol concentrations of 2–18%, depending on the amount and type of oat product, the amount of β-glucan,

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[2] Conflict of interest: SJB conducted the study while at the Beth Israel Medical Center and is now the vice president of research and development for Medical Foods, Inc, Cambridge, MA, who licensed the application for β-glucan fiber from Alpha-Beta Technology, Inc, Worcester, MA; RAF received research support from Medical Foods, Inc, and now serves on their Scientific Advisory Board; BRB is a consultant to Medical Foods, Inc and Alpha-Beta Technology, Inc and is a coinventor of the patent issued to Alpha-Beta Technology, Inc for the cholesterol-lowering properties of the yeast-derived fiber; RN is a consultant to Alpha-Beta Technology, Inc.

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and initial total cholesterol concentrations. A reduction in total cholesterol of just 1% could reduce heart disease mortality by 2% (7, 8).

Spent yeast (from breweries or bakeries) is a rich source of β-glucans. After processing, the yeast contains 85–90% β-glucan, consisting of repeating units of β-D-glucose joined together in β-(1→3) (1→6) linkages. Physically, the β-glucans are discrete, hollow microspheres that are highly miscible in most liquids and will not gel. β-glucan is composed of both soluble and insoluble fiber. Other soluble fibers such as pectin and psyllium tend to clump and gel when mixed with liquids.

The β-glucan from oat fiber has been shown to improve lipid profiles. The purpose of this study was to examine the effect on blood lipids of yeast-derived β-glucan fiber in hypercholesterolemic obese individuals to confirm that the yeast source of this fiber works in a similar way.

TABLE 2
Satiety, tolerance, and acceptability ratings during consumption of the yeast fiber supplement[1]

Supplement use rating	Mean	Median
Satiety[2]		
Fullness 1 h after fiber use	3.9	4
Fullness 2 h after fiber use	3.4	4
Fullness 3 h after fiber use	2.8	4
Fullness during the day after fiber use	3.3	4
Tolerance[3]		
Diarrhea	0.14	0
Nausea	0.09	0
Vomiting	0	0
Abdominal discomfort	0.19	0
Abdominal distension	0.15	0
Flatulence	0.37	0
Acceptability of product characteristics		
Thickness (1, too thin; 9, too thick)	5.2	5
Consistency (1, gritty or chalky; 9, smooth)	4.8	5
Color (1, unappealing; 9, appealing)	4.4	4
Flavor (1, unpleasant; 9, pleasant)	4.6	5
Aroma (1, unpleasant; 9, pleasant)	4.9	5
Aftertaste (1, nauseating; 9, delicious)	4.9	5

[1] n = 12.
[2] Based on a satiety scale from 0 (hungry) to 10 (extremely full).
[3] Based on a scale of severity from 0 (no adverse effects) to 3 (marked discomfort, unable to perform usual daily activity).

SUBJECTS AND METHODS

Subjects

Male subjects were selected from an obese population being treated at the Beth Israel Deaconess Medical Center's Nutrition Research Clinic; others responded to local newspaper advertisements. At entry, subjects were between the ages of 20 and 60 y, were ≥120% of ideal weight, and had serum total cholesterol concentrations >6.21 mmol/L (240 mg/dL). Candidates taking cholesterol-lowering medication or who had conditions that are secondary causes of hyperlipidemia such as hypothyroidism, diabetes mellitus, or renal disease were excluded from the study. The study protocol was approved by the Beth Israel Deaconess Medical Center Institutional Review Board.

Nineteen subjects entered the study but 4 of the 15 subjects dropped out during the 3-wk run-in period. A total of 15 subjects completed the study and had blood lipid data available for basal values, week 7, week 8, and week 12. Of the 15 subjects who completed the study, only 12 had data relating to anthropometry, nutrient intake (**Table 1**), and clinical tolerance (**Table 2**).

Study design and measurements

Each subject had 3 fasting blood samples drawn weekly over 3 wk for measurement of total cholesterol and triacylglycerols. These measurements were then averaged as the basal values for each patient. Both total cholesterol and HDL-cholesterol concentrations were measured directly. The concentrations of LDL cholesterol (mg/dL) were calculated according to the method of Friedewald et al (9): LDL cholesterol = total cholesterol − HDL cholesterol − (triacylglycerol/5). Cholesterol was converted from mg/dL to mmol/L by multiplying by 0.02586. Plasma triacylglycerols were converted from mg/dL to mmol/L by multiplying by 0.0112. After the third blood sample was taken, subjects were instructed in how to take 7.5 g yeast-derived β-glucan fiber in preweighed containers and add it to orange juice twice daily. Subjects returned weekly for 8 wk to be weighed and to obtain more fiber. They were not instructed to follow a special diet. Subjects completed weekly 3-d food records during the baseline (3 wk) and treatment (8 wk) periods. Fiber intake was confirmed by the number of empty containers returned. At weeks 7 and 8, 12-h fasting concentrations of plasma total cholesterol, LDL cholesterol, HDL cholesterol, and triacylglycerols were measured. Fiber supplementation stopped after 8 wk, but the subjects continued consuming the same amount of orange juice. Four weeks later (week 12), the subjects were weighed and had another fasting blood sample taken for measurement of total cholesterol, LDL cholesterol, HDL cholesterol, and triacylglycerol.

TABLE 1
Nutrient intakes, weight, and BMI of subjects before and after 8 wk of supplementation with yeast fiber[1]

	Baseline data	Treatment data
Intake		
Energy (MJ)	9.23 ± 2.16	11.61 ± 1.61
Dietary fiber (g)	17 ± 3	19 ± 4[2]
Fat (% of total energy)	32 ± 6	31 ± 6
Saturated fat (% of total energy)	11 ± 2	11 ± 3
Monounsaturated fat (% of total energy)	12 ± 3	12 ± 2
Polyunsaturated fat (% of total energy)	6 ± 1	7 ± 1
Weight (kg)	99 ± 9	98 ± 9
BMI (kg/m^2)	27.7 ± 5	27.5 ± 5

[1] $\bar{x}$ ± SD. Nutrient intake data available for 12 subjects; n = 15 for weight and BMI.
[2] Plus 15 g yeast fiber.

Each week the fiber was consumed, subjects completed questionnaires designed to gauge the effect of the product. Assessment was made of *1*) the degree of satiety (when the subject felt fullness and the general feeling of fullness throughout the day), *2*) product tolerance (abdominal discomfort, diarrhea, nausea, vomiting, and flatulence), and *3*) product acceptability (thickness, consistency, color, flavor, aroma, and aftertaste). Satiety was rated on a scale of 0 to 10, with 0 being "hungry" and 10 being "extremely full." Tolerance was assessed at 4 levels: 0 for no adverse effects, 1 for slight awareness, 2 for moderate discomfort, and 3 for marked discomfort. Product acceptability was rated on a scale of 1 to 9, with 1 being the worst attribute (eg, gritty, chalky consistency) and 9 the best attribute (eg, smooth consistency).

Statistical analyses

Data are presented as means ± SDs, except for satiety, tolerance, and acceptability, which are presented as means and medians. One-way analysis of variance (ANOVA) was used for univariate and multivariate repeated-measures analysis (more than one measurement of each subject) with the SYSTAT statistical software program (SYSTAT, Evanston, IL). Statistical significance was determined at the 95% confidence level. Group comparison between the baseline value and each of the treatment [week 7, week 8, and posttreatment (week 12)] weeks was determined by Bonferroni correction, only when ANOVA, as defined above, was found to be significant.

RESULTS

A total of 15 subjects completed the study. Subjects were middle-aged (51 ± 7 y) and overweight according to body mass index (in kg/m^2; 27.7 ± 5) (Table 1). Nutrient intake during the baseline and fiber-treatment periods was not different (9.23 ± 2.16 MJ at baseline compared with 11.61 ± 1.61 MJ during treatment) except for the fiber supplement during the treatment phase. All subjects consumed 15 g fiber daily in addition to their usual diet during the 8-wk study period. Subjects consumed sufficient energy to maintain their body weight during the study.

Changes in plasma lipids

Significant differences were found in total cholesterol ($P < 0.05$), LDL-cholesterol ($P < 0.001$), and HDL-cholesterol ($P < 0.005$ by one-way ANOVA with repeated measures; **Figures 1** and **2**) concentrations with β-glucan supplementation. After 7 wk of supplementation, serum total cholesterol concentration was significantly lower than at baseline (6.38 ± 0.44 compared with 5.90 ± 0.68 mmol/L; $P < 0.05$ by Bonferroni correction). At week 8, total cholesterol concentration was 5.98 ± 0.57 mmol/L, which was also significantly lower (by 6%) than at baseline ($P < 0.01$ by Bonferroni correction). There was no significant difference in total cholesterol concentration between baseline and week 12.

During the study period, HDL-cholesterol concentrations increased significantly ($P < 0.005$ by one-way ANOVA). The mean concentration tended to increase (by 9%) from 0.87 ± 0.25 mmol/L at baseline to 0.96 ± 0.26 mmol/L at week 8. However, a group difference was observed only between baseline and week 12 ($P < 0.05$ with Bonferroni correction), indicating a carryover effect even though the fiber supplementation had stopped 4 wk earlier. There was a 16% increase in HDL-cholesterol concentrations at week 12 compared with baseline values.

No significant differences were observed for LDL-cholesterol concentrations between baseline and weeks 7, 8, and 12 when individual groups were compared by using Bonferroni correction, even though the overall ANOVA with repeated measures was highly significant ($P < 0.001$). Compared with baseline values, LDL-cholesterol concentration tended to decline by 5% at week 7 and by 8% at week 8.

The mean ratio of total to HDL cholesterol declined during fiber supplementation, which was marginally significant ($P = 0.06$ by one-way ANOVA with repeated measures; **Figure 3**). However, the change in this ratio was significant by the single degree-of-freedom polynomial contrast ($P < 0.05$). Fiber supplementation led to a reduction in the ratio of total to HDL cholesterol from 8.2 at baseline to 7.3 at week 7 and to 7.0 at week 8 ($P < 0.05$ with Bonferroni correction). This ratio returned to baseline at week 12.

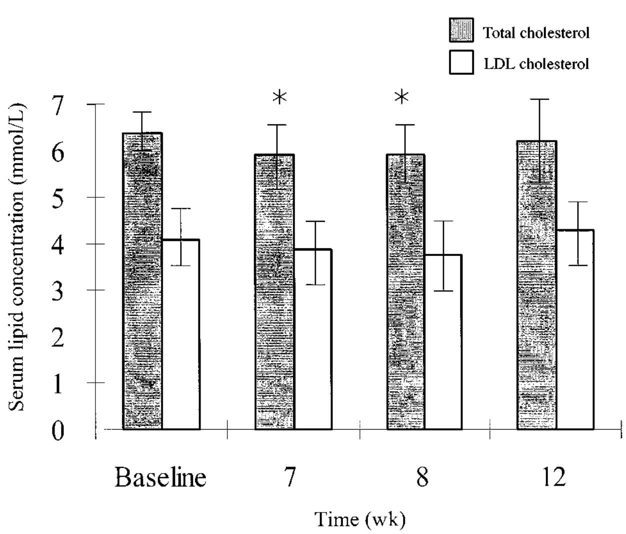

FIGURE 1. Mean (±SD) changes in serum total cholesterol and LDL-cholesterol concentrations during supplementation with yeast-derived β-glucan fiber (weeks 7 and 8) and after supplementation (weeks 8–12) ($n = 15$). Significant reductions were observed in concentrations of total cholesterol ($P < 0.05$) and LDL cholesterol ($P < 0.001$) by one-way ANOVA with repeated measures. *Significantly different from baseline, $P < 0.05$ (by Bonferroni correction).

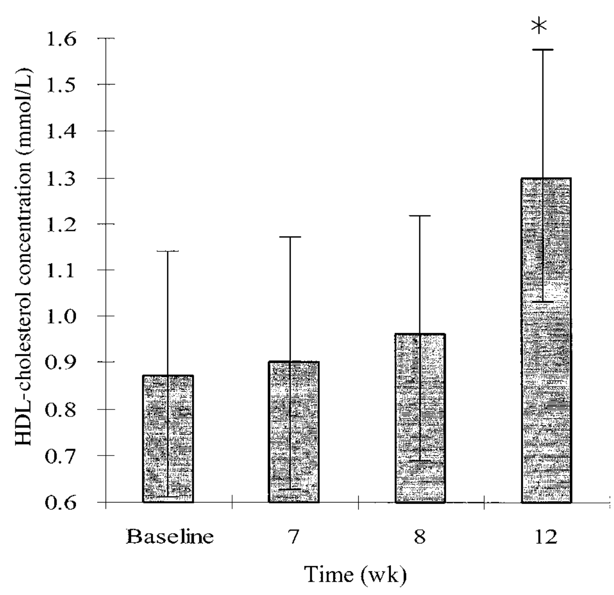

FIGURE 2. Mean (±SD) changes in serum HDL-cholesterol concentrations during supplementation with yeast-derived β-glucan fiber (weeks 7 and 8) and after supplementation (weeks 8–12) ($n = 15$). A significant difference was observed in the concentration of HDL cholesterol among time points, $P < 0.005$ (by one-way ANOVA with repeated measures). HDL-cholesterol concentration tended to increase from baseline to week 7 and week 8, but not significantly so. *Significant difference by group between baseline and week 12, $P < 0.05$ (by Bonferroni correction).

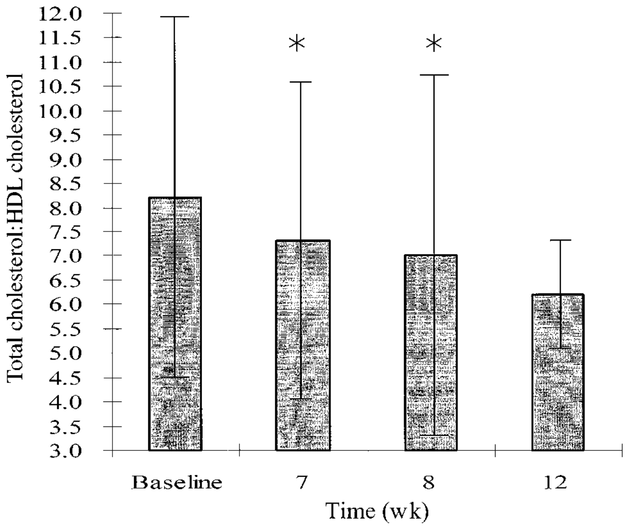

FIGURE 3. Mean (±SD) changes in the ratio of total to HDL-cholesterol concentrations during supplementation with yeast-derived β-glucan fiber (weeks 7 and 8) and after supplementation (weeks 8–12) (n = 15). Borderline overall significant decreases (P = 0.06) were observed with ANOVA with repeated measures. The overall decrease was significant by the single degree-of-freedom polynomial contrast ($P < 0.05$), as were individual comparisons between baseline and week 7 and baseline and week 8 ($^{*}P < 0.05$) by Bonferroni correction.

Satiety, tolerance, and acceptability

Data were available for 12 of the 15 participants. Six subjects stated that they never felt full after taking the fiber supplement; 5 felt full 5–20 min after ingestion. The remainder felt full from 20 to 60 min after ingestion. Most subjects (8 of 12) stated that they had no feeling of fullness beyond 3 h after ingestion of the fiber. When subjects rated fullness on a scale of 1 to 10, mean fullness ranged from 2.8, 3 h after ingestion of the fiber, to 3.9, 1 h after ingestion (Table 2).

Fiber effects such as diarrhea, nausea, abdominal discomfort, abdominal distension, and flatulence were minimal (<1, indicating slight awareness of symptoms that were easily tolerated). There were no reports of vomiting.

The product was moderately well accepted (Table 2). Each of the 6 attributes rated (thickness, consistency, color, flavor, aroma, and aftertaste) had a mean and median of 4 or 5 on a scale of 0 to 9.

DISCUSSION

Elevated plasma cholesterol and, in particular, LDL-cholesterol concentrations are associated with increased risk of coronary artery disease, whereas an elevated of HDL-cholesterol concentration is inversely correlated with the incidence of cardiovascular disease (3). A reduction in dietary saturated fat and cholesterol is the main treatment for patients with hypercholesterolemia (2). However, there is substantial evidence that dietary fiber such as that from oats (4, 5, 10) and psyllium (11) favorably affects serum lipid profiles. In this study, a new source of dietary fiber from yeast was evaluated in hypercholesterolemic subjects (baseline total cholesterol: 6.39 ± 0.44 mmol/L). Subjects also had an elevated ratio of total to HDL cholesterol (>4.98) throughout the study, which indicates an increased risk of coronary disease.

The yeast-derived β-glucan fiber lowered total cholesterol and raised HDL-cholesterol concentrations significantly. The use of dietary fibers rich in β-glucans from oats has a similar effect on serum lipids. Hypercholesterolemic subjects similar to those consuming the yeast-derived β-glucan in this study, who consumed oat products in addition to their usual diets, showed reduced total cholesterol concentrations. A review of 24 studies in which hypercholesterolemic subjects consumed oat products showed that total cholesterol concentrations declined by 0.8–26% (4). Two of these studies reported increases in total cholesterol concentrations. Six reported a decrease of <5% from baseline total cholesterol, 7 reported decreases of 5–10%, 6 reported decreases of >10% and <15%, and 2 reported decreases of 19.3% and 26%. (One study reported no data for total cholesterol.)

Oat products can be expected to reduce LDL-cholesterol concentrations by between 4.6% and 24%; 5 of the 24 studies reported no significant reduction and 4 did not report data on LDL-cholesterol concentration (4). Nine studies reported that subjects experienced reductions in LDL-cholesterol concentrations of ≤10%. This is similar to what was found when comparable subjects were given yeast-derived β-glucan. Only 6 of the studies using oat products showed greater reductions in LDL-cholesterol concentrations.

Unlike the significant increases in HDL-cholesterol concentrations observed 4 wk after the end of the study for subjects receiving the yeast-derived β-glucan, none of the 24 studies of oat products reported significant changes in HDL concentration. Moreover, psyllium alone does not appear to raise HDL-cholesterol concentration (11). However, when psyllium was consumed in conjunction with an NCEP Step I diet that was low in dietary fat, saturated fat, and cholesterol, HDL-cholesterol concentrations increased in healthy children aged 2–11 y (12). Because higher HDL-cholesterol concentrations are associated with a reduced risk of developing coronary artery disease, there may be unique benefits of using the yeast-derived β-glucan, and perhaps psyllium, rather than the oat products.

HDL-cholesterol concentrations did not increase immediately with consumption of the yeast β-glucan fiber, rather, it took 12 wk, which was 4 wk after the cessation of the yeast β-glucan fiber supplement. The mechanism for the increase in HDL-cholesterol concentrations with the yeast product is unknown. It may be that the amount of β-glucan is the key determinant of whether HDL-cholesterol concentration increases. Twelve grams of yeast β-glucan were administered in this study; most of the studies in which oats were evaluated provided only 3 g β-glucan (4, 6). When 14 healthy subjects consumed a higher amount of β-glucan from oat gum (9 g), HDL-cholesterol concentrations increased (13). Beer et al (13), however, argued that the solubility and viscosity of the β-glucan are more important than the amount consumed for the effect on serum lipids. An increase in HDL-cholesterol concentrations was observed when oat gum was used (in contrast with oat bran) and the authors attributed this to the low solubility and the moderate molecular weight of the oat gum, which resulted in low viscosity in the gut (13). The yeast β-glucan used in this study also had a low solubility and a low viscosity. Thus, it is not apparent whether the high amount of β-glucan or its low viscosity contributed to the increases in HDL- cholesterol concentrations because we and Beer et al used materials with both properties.

The changes in blood lipid concentrations with supplementation with oat products varied substantially between studies. The wide variation may be due to several factors (4). First, it is likely that baseline serum lipid concentrations affected how much serum lipid concentrations changed. Subjects with baseline serum total cholesterol concentrations >6.2 mmol/L had the greatest absolute reductions. We would expect to observe the same phenomenon with the yeast fiber. Second, subjects received different quantities of oat products (7.2–110 g). The largest quantities of oat products did not always result in the greatest reductions in serum lipid concentrations. Rather, the type, form, and soluble fiber and β-glucan content dictated changes in serum lipid concentrations. It may be possible to obtain significant reductions in total cholesterol and LDL cholesterol with less yeast fiber. Third, the duration of the study may have influenced the results on serum lipid concentrations, although there was no direct correlation between duration of the study and the percentage change in serum lipid concentrations. Three weeks of oat product use appeared to be adequate to cause an observable effect. Because serum concentrations were not measured before 6 wk, we do not know whether significant reductions occurred sooner than this. To our knowledge, this is the only study published on the yeast β-glucan product.

Others have reported that the soluble fiber psyllium can reduce serum total cholesterol concentrations (14). Subjects who received 10.2 g psyllium seed husk for 24 wk experienced a 5.3% reduction in LDL-cholesterol concentrations compared with a control group. This is similar to our findings for subjects who used the yeast-derived β-glucan and to those who used oat products (4). However, in addition to the psyllium, the subjects followed the NCEP Step I diet, which alone reduces LDL-cholesterol concentrations. Thus, it appears that the yeast fiber and oat products may cause a greater reduction in LDL-cholesterol concentrations than psyllium alone. HDL-cholesterol concentrations did not increase in this study of adults (14), unlike the study in children cited earlier (12).

Data were compiled from 5 published studies in which subjects followed the NCEP Step II diet alone (2). This diet is another way to reduce the risk of developing coronary artery disease by lowering serum total cholesterol and LDL-cholesterol concentrations. The average decrease in LDL cholesterol was 18.9% for men (baseline: 3.67 ± 0.88 mmol/L) and 15.6% for women (baseline: 3.44 ± 1.09 mmol/L). This effect was greater than what was reported for oat products and for yeast-derived β-glucan, but it was negated by a significant decrease in HDL-cholesterol concentrations ($P < 0.0001$).

The yeast-derived β-glucan was well-tolerated in modest amounts and produced results similar to those of oat products. More volume and energy from the oat products must be consumed than of the yeast fiber to bring about a significant effect on serum lipid concentrations. The yeast-derived β-glucan fiber has an added benefit over the NCEP Step II diet because it raises HDL-cholesterol concentrations, whereas the diet reduces them. Thus, the yeast product may be superior to oat products because of its unique effect on HDL-cholesterol concentrations and its greater concentration of the active ingredient, β-glucan. The relative efficiency of yeast-derived β-glucan compared with that of the NCEP Step II diet is probably best assessed in terms of the ratios of LDL to HDL cholesterol and of total to HDL cholesterol, which are similar. Yeast-derived β-glucan reduces LDL-cholesterol concentrations less and increases HDL-cholesterol concentrations more than does the NCEP Step II diet. It would be interesting to study whether there would be additional benefits of yeast-derived β-glucan fiber when combined with an NCEP Step II diet because LDL-cholesterol concentrations might be lowered further and HDL-cholesterol concentrations may be restored or increased over baseline values. This combination might obviate the need for drugs in some cases.

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