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Consumption of Oat Milk for 5 Weeks Lowers Serum Cholesterol and LDL Cholesterol in Free-Living Men with Moderate Hypercholesterolemia

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Key Words

Low-density lipoprotein cholesterol · Oat milk · Moderate hypercholesterolemia · β-Glucan · Soluble fiber

Abstract

The aim of this study was to investigate whether consumption of a newly developed oat milk deprived of insoluble fiber would result in lower serum cholesterol and low-density lipoprotein (LDL) cholesterol levels in men with moderate hypercholesterolemia. The study had a randomized, controlled double-blind design, and oat milk was compared with an identically flavored control drink. Sixty-six men were recruited from a screening program and were randomly assigned to two groups. Each group took either oat milk or a control drink (rice milk) for 5 weeks (0.75 liters/day) and then switched to the other drink regimen for another 5-week period with a 5-week washout period between the test periods. The oat milk contained more dietary fiber, especially β-glucan (0.5 g/100 g), than the control drink (<0.02 g/100 g). Both drinks were well appreciated and got similar sensory evaluation, indicating that the double-blind design had been attained. In the final analysis 52 subjects remained. Compared with the control drink, intake of oat milk resulted in significantly lower serum total cholesterol (6%, $p = 0.005$) and LDL cholesterol (6%, $p = 0.036$) levels. The decrease in LDL cholesterol was more pronounced if the starting value was higher ($r = -0.55$, $p < 0.001$). The concentration of high-density lipoprotein cholesterol was not significantly different after consumption of the two drinks. Serum triglycerides did not change signifi-

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cantly after intake of oat milk, but a significant increase was observed after intake of the control drink (p = 0.003). It is concluded that also oat milk deprived of insoluble fiber has cholesterol-reducing properties.

Introduction

A raised serum cholesterol concentration is associated with an increased risk of ischemic heart disease [1], and recent data indicate that the association may be stronger than believed previously [2]. Even if the risk increases with increasing cholesterol level, most coronary events occur in subjects having serum cholesterol concentrations in the midrange. From a public health perspective, it is, therefore, important to find out regimens that lower the serum cholesterol levels. One strategy to decrease the disease risk is to recommend an increased use of food products having a high nutritional value and a cholesterol-lowering effect.

Much interest has been devoted to the effects of different dietary fats, and a meta-analysis confirmed that intake of saturated fats increases and intake of unsaturated fats decreases serum cholesterol [3]. Moreover, foods containing soluble dietary fiber have been shown to decrease the serum cholesterol concentration, probably by reducing the cholesterol and bile acid absorption [4]. Another suggested mechanism for the hypocholesterolemic effect of soluble fiber is a delay in lipid digestion.

Oat has a high content of soluble fiber, most of which is β-glucans [5], and it also contains high amounts of unsaturated fatty acids. To widen and increase the usefulness of oat, an oat-based milk has been developed based on new technology. The oat milk is made from steam-prepared or heat-treated oat flakes or oat flour and is rich in β-glucans. The manufacturing process (US patent No. 5686123) includes dry milling or wet milling of the flakes at 60 °C, followed by an enzymatic reaction step using essentially β-amylase. In this way maltose and β-limit dextrins, being the main carbohydrate species in the final product, are formed from the starch. Maltose has approximately the same degree of sweetness as lactose. After the enzymatic step of the process, insoluble fibers can be optionally separated using a decanting step. The product obtained, high or low in insoluble fiber, can be further modified by addition of oil, nutrients, and flavors.

In a recent study [6] healthy subjects with normal serum lipid levels consumed 0.75–1 liter/day of oat milk during 4 weeks which gave a significant lowering of serum cholesterol and low-density lipoprotein (LDL) cholesterol. Oat milk was well tolerated and got high ratings at sensory evaluation. Similar results were obtained in women with moderate hypercholesterolemia [Wallmark et al., unpubl. data]. The present intervention study was performed to study the cholesterol-reducing properties in hypercholesterolemic men of an oat milk deprived of insoluble fiber, using a double-blind design.

Materials and Methods

Subjects

Sixty-six men with moderate hypercholesterolemia were recruited from persons attending a prospective screening program, the Malmö Diet and Cancer Study [7]. The Ethics Committee of the Medical Faculty of the Lund University approved the study, and all subjects gave written formal consent. Subjects were randomly assigned to two groups (A or B), and each group followed one dietary regimen for 5 weeks and then the other dietary regimen for another 5 weeks in a cross-over design with a 5-week washout interval between the diet periods. In the final analysis 52 subjects remained when 14 subjects had been excluded either due to newly diagnosed disease (n = 2), unwillingness to continue the regimen (n = 8), high serum triglyceride level (>8 mmol/l; n = 1), or other reasons (n = 3).

Dietary Regimens

Oat milk was made 50% from commercial oat flakes (v. Freija; Kungsörnen, Vårgårda, Sweden) and 50% from a heat-treated, dry-milled oat bran fraction (Skånemöllan, Tågarp, Sweden). In the manufacturing process the insoluble fibers were separated by decanting. Rice milk based on brown rice and safflower oil was the base for the control drink. To both oat milk and rice milk the same flavor was added having black currant as the most prominent component. The drinks were analyzed for protein, fat, different carbohydrates, and dietary fibers by an authorized laboratory (Agro-Lab, Kristianstad, Sweden), as shown in table 1. The oat milk had higher dietary fiber and β-glucan contents as compared with the control drink, while the energy contents were similar for both drinks.

During one experimental period the subjects drank 0.75 liters of oat milk and during the other period 0.75 liters of the control drink. Both drinks were produced within 2 weeks prior to the beginning of the study, packed in unlabeled 0.25 l Tetra Brik® aseptic packages, and stored in the cold. Drinks were delivered at intervals to the homes of the participants. The subjects were instructed to consume the drinks on several occasions over the day, and they were asked not make any dietary or lifestyle changes other than the substitution of the test milks for their usual beverages.

Examination of the Subjects

On the first and last day of each dietary period, blood was collected after an overnight fast from the antecubital vein. Body weight and heart rate were measured, and the blood pressure was obtained using a sphygmomanometer on the right upper arm with the patient in the sitting position. The first visit also included measurement of height, and the body mass index (BMI) was calculated as weight in kg/(height in m)^2.

Biochemical Analysis

Blood glucose was determined by employing a hexokinase method. Serum triglycerides and total cholesterol were measured on a DAX 48 automatic analyzer using reagents and calibrators provided by the supplier (Bayer Norden, Malmö, Sweden). Serum high-density lipoprotein (HDL) cholesterol was determined by the same procedure as used for total cholesterol after precipitation of the other lipoproteins with dextran sulfate. LDL cholesterol was calculated according to Friedewald's formula [8]:

LDL cholesterol = total cholesterol – HDL cholesterol – (triglycerides/2.2).

Table 1. Composition of the test drinks (g/100 g)

Component	Oat milk	Control drink
Energy, kJ/kcal	264/63	258/61
Fat	1.3	0.9
Protein	0.7	0.2
Carbohydrate	12	13
Dietary fiber	1.1	0.2
β-Glucan	0.51	<0.02
Maltose	3.9	5.9
Glucose	0.6	0.8

Sensory Evaluation

The test drinks were evaluated after each dietary period. The participants were given questionnaires concerning aroma, consistency, flavor, and total evaluation of the test drinks. A nine-graded scale was used, from dislike very much (grade 1) to like very much (grade 9).

Statistical Analysis

All variables except sensory variables were tested with the Kolmogorov-Smirnov goodness-of-fit test for normality. Since serum triglycerides were not normally distributed, this variable was $\log_{10}$ transformed before further calculations. Combined data from the two subject groups after consumption of oat milk were compared with combined data from the two groups after the control drink. Responses were evaluated for significance using the paired t test and a statistical software program (SPSS for Windows, version 6). Sensory responses were evaluated for significance using the Wilcoxon nonparametric test. All tests were two tailed, and $p < 0.05$ was considered significant. Results are presented as mean values ± SD unless otherwise indicated.

Results

Subject Examination

The data obtained at the initial clinical examination of the subjects are shown in table 2. At the start of the study, the mean age was 62.6 (range 52–70) years, the BMI was 27 (range 21–36) kg/m^2, and the fasting serum cholesterol level was 6.5 (range 5.0–

Table 2. Baseline characteristics of the subjects (mean ± SD)

	Group A: Oat milk/control drink (n = 29)	Group B: control drink/oat milk (n = 23)
Age, years	62.9 ± 5.9	62.2 ± 5.1
Body weight, kg	84.6 ± 11.8	85.9 ± 10.5
Height, cm	175.9 ± 7.3	179.0 ± 7.5
BMI, kg/m^2	27.4 ± 3.6	26.8 ± 3.0
Blood pressure, mm Hg		
Systolic	139 ± 11	143 ± 16
Diastolic	88 ± 7	89 ± 8
Pulse rate, beats/min	68 ± 8	66 ± 11
Fasting blood glucose, mmol/l	5.6 ± 0.6	5.3 ± 0.5
Serum levels, mmol/l		
Total cholesterol	6.6 ± 0.7	6.3 ± 0.6
LDL cholesterol	4.4 ± 0.8	4.4 ± 0.6
HDL cholesterol	1.4 ± 0.3	1.4 ± 0.3
Triglycerides	1.6 ± 0.8	1.4 ± 0.4
LDL/HDL ratio	3.2 ± 0.9	3.4 ± 1.0

Table 3. Sensory evaluation of the test drinks (mean ± SD; n = 52)

	Oat milk	Control drink	Z[a]	p
Aroma	6.6 ± 1.8	6.5 ± 1.9	–0.22	n.s.
Consistency	7.0 ± 1.9	7.5 ± 1.7	–2.46	0.014
Flavor	7.2 ± 1.7	7.3 ± 1.9	–0.76	n.s.
Total evaluation	7.2 ± 1.6	7.2 ± 2.0	–0.26	n.s.

The different parameters were evaluated on a nine-graded scale from dislike very much (grade 1) to like very much (grade 9).

[a] Wilcoxon matched-pairs signed-rank test.

8.5) mmol/l. Age, BMI, blood pressure, heart rate, and blood glucose and serum lipoprotein levels were not significantly different between the two groups starting with either oat milk or control drink.

Sensory Evaluation

The subjects evaluated the drinks using a nine-graded scale (table 3). Mean scores for the total evaluation were 7.2 for both drinks, and the scores were also similar for aroma and flavor, while the control drink got a significantly higher score for consistency. No special remarks about the flavor were given besides that the drinks tasted of black currant. This indicates that the double-blind design had been attained, i.e., the subjects could not with certainty identify oat milk and control drink.

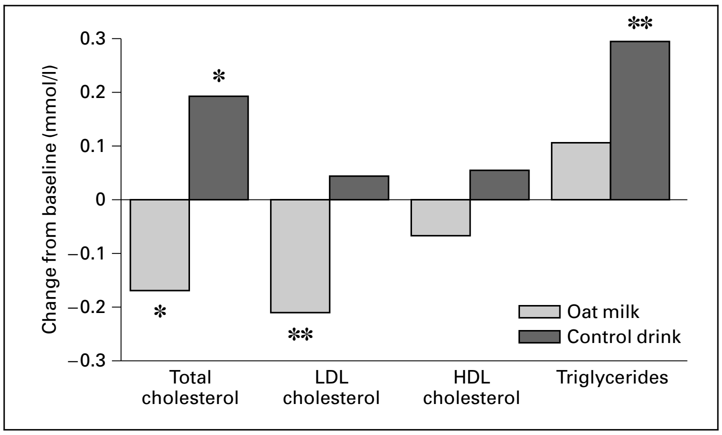

Fig. 1. Change in serum lipid levels from baseline after consumption of oat milk or control drink. * $p < 0.05$; ** $p < 0.01$.

Table 4. Serum lipid values (mmol/l) at baseline and after 5 weeks of oat or control drink diet (mean ± SD)

	Baseline	After 5 weeks	Change	% change	p (change)	p (oat-control)
Total cholesterol (n = 52)						
Oat milk diet	6.42 ± 0.66	6.25 ± 0.67	–0.17 ± 0.59	–3	0.045	
Control drink diet	6.39 ± 0.68	6.58 ± 0.80	+0.19 ± 0.54	+3	0.013	0.005
HDL cholesterol (n = 52)						
Oat milk diet	1.43 ± 0.51	1.37 ± 0.33	–0.07 ± 0.46	–5	n.s.	
Control drink diet	1.34 ± 0.33	1.39 ± 0.34	+0.05 ± 0.17	+4	0.051	n.s.
LDL cholesterol (n = 51)						
Oat milk diet	4.35 ± 0.65	4.14 ± 0.56	–0.21 ± 0.45	–5	0.002	
Control drink diet	4.34 ± 0.66	4.38 ± 0.82	+0.04 ± 0.62	+1	n.s.	0.036
LDL/HDL ratio (n = 51)						
Oat milk diet	3.30 ± 0.86	3.16 ± 0.78	–0.14 ± 0.43	–4	0.022	
Control drink diet	3.42 ± 1.05	3.32 ± 1.07	–0.10 ± 0.56	–3	n.s.	n.s.
Triglyceride (n = 52)[a]						
Oat milk diet	1.57 ± 0.74	1.67 ± 0.67	+0.10 ± 0.58	+6	n.s.	
Control drink diet	1.56 ± 0.69	1.85 ± 0.92	+0.29 ± 0.63	+19	0.003	n.s.

[a] The statistical analysis was performed on $\log_{10}$-transformed data.

Blood Lipid Levels

Compared with the control drink, the intake of oat milk resulted in significantly lower (6%) concentrations of total cholesterol and LDL cholesterol (table 4, fig. 1). The concentration of HDL cholesterol did not change significantly after consumption of the two drinks. The LDL/HDL ratio decreased significantly after consumption of oat milk but not after consumption of the control drink, but

Table 5. Body weight, systolic and diastolic blood pressures, pulse, and blood glucose level at baseline and after 5 weeks of oat or control drink diet (mean ± SD; n = 52)

	Baseline	After 5 weeks	Change	% change	p (change)	p (oat-control)
Body weight, kg						
Oat milk diet	85.0 ± 11.2	85.6 ± 11.0	+0.6 ± 1.1	+1	<0.001	
Control drink diet	84.8 ± 11.3	85.5 ± 11.5	+0.6 ± 1.2	+1	0.001	n.s.
Blood pressure, mm Hg						
Systolic						
Oat milk diet	138.7 ± 14.3	139.6 ± 16.5	+0.9 ± 14.6	+1	n.s.	
Control drink diet	139.4 ± 14.7	141.9 ± 15.6	+2.5 ± 10.7	+2	n.s.	n.s.
Diastolic						
Oat milk diet	87.1 ± 7.2	88.2 ± 10.9	+1.0 ± 10.2	+1	n.s.	
Control drink diet	85.8 ± 7.8	88.3 ± 8.0	+2.5 ± 7.8	+3	0.023	n.s.
Pulse rate, beats/min						
Oat milk diet	66.9 ± 8.2	68.1 ± 7.9	+1.2 ± 6.4	+2	n.s.	
Control drink diet[a]	66.4 ± 9.7	68.4 ± 8.6	+2.0 ± 6.3	+3	0.025	n.s.
Blood glucose, mmol/l						
Oat milk diet	5.5 ± 0.6	5.4 ± 0.6	–0.1 ± 0.4	–2	n.s.	
Control drink diet	5.5 ± 0.7	5.5 ± 0.6	0.0 ± 0.6	0	n.s.	n.s.

[a] n = 51.

there was no significant difference between the responses after consumption of the two drinks. Serum triglycerides did not change significantly after intake of oat milk, but increased significantly by 19% after intake of the control drink. Further analysis of the changes in serum lipid levels after intake of oat milk showed that the higher the initial serum LDL cholesterol level, the more pronounced the lipid-lowering response ($r = -0.55$, $p < 0.001$). The changes in serum lipids were not related to body weight or BMI.

Other Variables

Among other variables, fasting blood glucose, systolic and diastolic blood pressures, and heart rate showed only minor and mostly nonsignificant changes during the study (table 5). The body weight increased by 0.6 kg after consumption of both drinks. This may to some extent reflect the fact that the subjects did not fully decrease the intake of other energy-containing drinks when consuming the test drinks. This effect is, however, a minor one, since it could be calculated that a possible deposition as body fat of all the energy consumed in the test drinks during 5 weeks would result in formation of approximately 2.5 kg adipose tissue.

Discussion

A moderately elevated level of cholesterol in blood serum is a well-known risk factor for coronary heart disease. The decrease over time in serum cholesterol in Swedish subjects was associated with a decreased incidence of and mortality from coronary heart disease [9]. Strategies to lower serum lipid levels have been recommended in subjects with elevated serum lipid concentrations [1]. The subjects recruited for this study had 10–15% higher mean total cholesterol and LDL cholesterol levels than found recently in a well-characterized Swedish population [9]. It is worth mentioning that recent trials using statins have shown positive effects on cardiovascular disease end points also in subjects with normal serum lipid levels [10]. The intake of a number of dietary components can lower serum cholesterol and LDL cholesterol levels. In this context, increasing attention has been focused on oat-containing foods, since they contain several components that may be beneficial to the serum lipid profile. A result of this interest was that the Food and Drug Administration [11, 12] after a thorough literature review approved health claims on the benefit of using foods containing unprocessed oats that contain specified amounts of soluble fiber (β-glucans). The Food and Drug Administration also stressed that for processed oat products a specific documentation would be required.

This study shows that consumption of oat milk deprived of insoluble fiber results in lower total cholesterol and LDL cholesterol level as compared with a control cereal drink. Different calculations can be made on the medical importance of the difference in serum cholesterol between the oat milk and control drink regimens of 0.36 mmol/l (table 4). Law et al. [2] found that a prolonged difference in serum cholesterol of 0.6 mmol/l was associated with an almost 30% reduction in the risk of coronary heart disease. According to Mensink and Katan [3] epidemiological data and clinical trials suggest that each 0.026-mmol/l increment in LDL cholesterol causes an increase in coronary risk of 1%. The difference between the groups in LDL cholesterol of 0.25 mmol/l observed in the present study would thus be expected to confer approximately 10% lower risk. Another meta-analysis indicated that a decrease in total cholesterol and LDL cholesterol by 5% would be equivalent to a complete adherence to current recommendations with respect to fat intake [13]. Moreover, the lower serum cholesterol level by 0.36 mmol/l found after oat milk intake was higher than the summary effect size of 0.13 mmol/l found in a meta-analysis of lipid-lowering properties of oat products [14]. It is also very close to the value of 0.41 mmol/l found for studies in which the initial cholesterol levels were >5.9 mmol/l and >3 g of soluble fiber from oats per day was used [14]. The present form of oat fiber thus seems to have the expected quantitative cholesterol-lowering effect as compared with less processed oat products.

The content of dietary fiber in oat milk may be largely responsible for the observed LDL cholesterol lowering effect. In the meta-analysis performed by Ripsin et al. [14] intervention studies using 1.1–7.6 g/day of soluble oat fiber were included. The serum cholesterol lowering effect was higher in studies using more than 3 g of soluble fiber than in those using lower doses. In the recent Food and Drug Administration authorization of a health claim on the association between oats and reduced risk for coronary heart disease [11], it was stated that the food shall contain no less than 20 g oatmeal or 13 g oat bran, providing at least 1 g of β-glucan soluble fiber per reference amount customarily consumed. In the final rule [12], the intention was to include whole oat food, i.e., oat bran, rolled oats, and whole-oat flour, providing at least 0.75 g of soluble fiber per reference amount customarily consumed. This amount of soluble fiber would be provided by a modest amount (0.15 liters) of oat milk. The daily amount of β-glucan from oat milk consumed in the present study was calculated to be 3.8 g.

In a study using purified β-glucan a similar cholesterol-lowering effect was obtained [15].

The selection of rice as the ingredient of the control drink was based on previous studies showing that rice bran had a smaller (or no) effect on serum cholesterol as compared with oat bran [16, 17]. Moreover, the rice product had a very low fiber content, but was otherwise similar in composition to oat milk.

The increase in serum triglycerides after consumption of the control drink was unexpected. It could have been related to body weight changes, but no relevant associations of triglyceride values with body weight change and metabolic and clinical variables were observed in the statistical analysis. Theoretically, the higher concentration of serum triglycerides after rice milk intake could be due to any component in this drink, but previously no such effect was evident in intervention studies using rice bran [16, 17]. The mechanism of the higher serum triglyceride response after rice milk may be related to the finding of a lower serum triglyceride response after a meal containing oat bran as compared with a meal with rice bran [18]. Furthermore, oat milk and control drink contained only approximately 15% of their energy as fat, and it has been argued that substitution of carbohydrate for saturated fats in the diet may lead to increased serum triglyceride levels, even if the serum cholesterol level is lowered [19]. On the other hand, a recent study on a carbohydrate-rich diet in a free-living population indicated only a nonsignificant increase (approximately 10%) in serum triglycerides [20] which is compatible with our findings.

Previously, it was shown that healthy subjects and women with moderate hypercholesterolemia well tolerated the daily use of whole oat milk and that such a regimen leads to lower levels of serum and LDL cholesterol [6; Wallmark et al., unpubl.]. The present study extends these findings to men with moderate hypercholesterolemia and to oat milk deprived of insoluble fiber. Moreover, a similar preparation, an oat-based soup, was previously used as a component in a weight-reducing regimen [21]. There is thus increasing evidence that not only solid oat foods but also oat-based liquid foods have beneficial health effects.

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