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Effects of Consumption of Oat Milk, Soya Milk, or Cow's Milk on Plasma Lipids and Antioxidative Capacity in Healthy Subjects

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Key Words
Oat milk
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Sensory evaluation

Abstract

A drink based on oats has been developed with new technology. In this study the effects of this oat milk, soya milk and cow's milk on plasma lipid, glucose, insulin, and antioxidant status (measured as the ability of serum to suppress the formation of the radical cation $ABTS^{\bullet+}$) were compared in 24 healthy men and women. Half of the subjects (group A) consumed 0.75–1 liters/day of oat milk and soya milk for 4 weeks each, and the other half (group B) consumed oat milk and cow's milk for two 4-week periods. In the combined groups A plus B the oat milk regimen resulted in decreased plasma cholesterol (4%) and low-density lipoprotein (LDL) cholesterol (9%) levels as compared with baseline, but no changes in high-density lipoprotein cholesterol (HDL) and triglyceride values were observed. Also soya milk consumption resulted in decreased LDL cholesterol concentrations. The only significant plasma lipid change observed during consumption of cow's milk was an increase in HDL cholesterol. No consistent changes in body weight, fasting blood glucose, serum insulin, and antioxidant status occurred after consumption of any milk regimen. A significant correlation between baseline antioxidant status and total plasma cholesterol was found ($r = -0.56$). It is proposed that the high content of β-glucans in oat milk was responsible for the decreased plasma cholesterol and LDL cholesterol concentrations, but the effect could also be due to a replacement of saturated fat in the customary diet by unsaturated fat. It is concluded that oat milk can be used as an alternative to other milk drinks by subjects who would benefit from reduced LDL cholesterol values.

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Introduction

Increased serum cholesterol levels are associated with an increased risk of the development of coronary heart disease. Epidemiological data and clinical trials suggest that each 0.026 mmol/l (1 mg/100 ml) increment in low-density lipoprotein (LDL) cholesterol causes an increase in coronary risk of 1% [1]. From a public health perspective, it is, therefore, important to lower the plasma cholesterol levels in many industrialized countries. The majority of coronary events occur in the large number of subjects having cholesterol concentrations in the midrange [2]. For these people an increased use of food products having a high nutritional value and a cholesterol-lowering effect could be one strategy to decrease disease risk.

Foods that contain soluble dietary fibers like β-glucans have been shown to decrease the plasma cholesterol concentration, probably by reducing the absorption of cholesterol and bile acids [3]. Another suggested mechanism for the hypocholesterolemic effect is that soluble fibers delay lipid digestion.

Oats contain 3–5% β-glucans [4] and have well-documented plasma cholesterol lowering effects [5, 6]. Daily consumption of an oat-based soup for 6 months (375 ml containing 4 g dietary fiber) resulted in reduced plasma cholesterol concentration from 5.6 to 5.2 mmol/l in healthy subjects [7]. The soup used was part of an energy-restricted regimen, and the mean body weight of the subjects was reduced from 83 to 77 kg. The lipid content in oats is relatively high (5–9%) as compared with that in other cereals, but the fatty acids are primarily unsaturated [8]. Several studies have shown that soya also has a plasma cholesterol lowering effect [9]. Soya contains soluble fiber, but intake of soya protein seems also to reduce the plasma cholesterol level [10]. Soya protein may result in upregulation of LDL receptors that are depressed in hypercholesterolemia [9].

Today, dairy products make an appreciable contribution to saturated fat intake in industrialized countries, e.g., Sweden. The consumption of dairy products correlated with the incidence of coronary heart disease in 40 countries [11]. The only exception was France that showed a similar intake of cholesterol and saturated fat as Finland, but a lower coronary heart mortality rate. This paradox was explained by a higher consumption of plant foods (containing unsaturated fatty acids) in France that could be protective. Moreover, intervention studies have shown that the intake of saturated fatty acids with 12–16 carbon atoms results in increased plasma cholesterol levels [1]. It is, therefore, important to reduce the intake of saturated fat and also to replace it with products that contain unsaturated fatty acids. With the aim to produce such new foods, an oat milk was developed. In the present study, the effect of incorporating this oat milk in the diet was investigated, and it was compared with soya milk and cow's milk. The tolerability and the lipid-lowering effect were determined for the different milks. Also the effects on the antioxidative capacity of blood and on fasting blood glucose and insulin concentrations were investigated.

Materials and Methods

Subjects

Participants were recruited by local advertisement at the University of Lund. Twenty-four healthy, nonsmoking volunteers (mainly university employees and students) entered the study after giving informed consent. Twelve women and 12 men with a normal body mass index of 20–25 kg/m^2 and an age of 23–54 years were selected. The average age was 36 years for the women and 27 years for the men. The Ethics Committee of the University of Lund had approved the study.

Study Design

During a baseline period of 3 weeks, fasting blood samples and body weight were determined twice for each participant. The subjects were then randomized into two groups according to age and gender, and both groups had a mean age of 31.5 years and consisted of 6 women and 6 men. Group A received oat milk for 4 weeks and soya milk for 4 weeks. Group B was also given oat milk for one period, but instead cow's milk for the other 4-week period. Half of the groups started with oat milk while the other half began with soya or cow's milk. There was no washout period between the test periods. Blood samples and body weight were taken twice during the 4th week in both test periods.

Intervention Diets

The oat milk was prepared from steam-treated oats, water, and rapeseed oil according to a Swedish patent and was obtained from Mill milk, (Scanian Farmers, Malmö, Sweden). Analysis of the nutrient composition in oat milk was done by Agrolab Scandinavia (Kristianstad, Sweden). The soya milk was Tofuline (sweetened, Carlshamn Mejeri, Sweden), and the cow's milk was a medium-fat milk (Tesco Stores, UK). The nutrient composition was obtained from the producers. A separate analysis of the β-glucan content in the test was done according to McCleary and Codd [12]. All liquids were UHT treated.

The nutrient composition of the different test milks is shown in table 1. They had a similar energy and fat content. The women drank 0.75 liters and the men 1 liter of the test milk each day. In this way both women and men got approximately the same energy contribution, approximately 14% of the recommended daily intake, from the milks. The total amount of dietary fiber differed in the milks, the oat milk containing 6.6 g, soya milk 5.6 g, and cow's milk 0 g/l. β-Gulcans were detected in oat milk (4.5 g/l) but not in soya and cow's milk.

The subjects were requested to consume the milk evenly over the day and also to make a detailed record of their food consumption during the first period of 4 weeks. They were then asked to repeat this food consumption as much as possible during the second period, so that the test milk would be the main dietary difference between the test periods. As a help to make the food intake equal for both periods, frozen dishes (Findus, Nestlé, Bjuv, Sweden) were provided for dinner 5 days per week. The subjects were also asked to maintain their usual pattern of activity and try to keep a stable body weight.

Table 1. Nutrient composition (per liter) of the different test milks

	Oat milk	Soya milk	Cow's milk
Energy, kJ	1,760	1,900	1,990
Protein, g	15	30	34
Fat, g	15	20	17
Carbohydrates, g	54	40	49
Dietary fiber, g	6.6	5.6	–
β-Glucan, g	4.5	–	–

Sensory Evaluation

The participants were given questionnaires after 1 and 3 weeks during both test periods. Questions about appearance, smell, consistency, flavor, and general impression of the test milks were answered on a nine-grade scale, from dislike very much to like very much.

Blood Sampling

Fasting venous blood samples were taken twice during the baseline period and twice during week 4 of both test periods. The blood was collected in two tubes, one containing EDTA to obtain plasma and one without anticoagulant for isolation of serum. The separation was accomplished by centrifugation at 2,500 *g* for 10 min.

Analysis of Glucose, Lipids, and Insulin

Glucose was analyzed directly in EDTA-containing blood using a Reflotron instrument (Boehringer Mannheim, Germany). This equipment was also used to analyze total cholesterol and high-density lipoprotein (HDL) cholesterol in plasma within 24 h. HDL was separated by precipitation of the other plasma lipoproteins with magnesium ions and dextran sulfate. The apparatus was checked throughout the analysis with control serum: Precinorm U (glucose, total cholesterol) and Precinorm HDL. Analysis of triglycerides was done on plasma that had been frozen, using Sigma kit No. 336 (St. Louis, Mo., USA). LDL cholesterol was calculated using the formula of Friedewald et al. [13]. A radioimmunoassay was used to determine serum insulin [14].

Analysis of Total Antioxidant Status

The total antioxidant status was determined in serum within 18 h using a kit from Randox Laboratories (Crumlin, UK). The assay is based on incubation

Table 2. Sensory evaluation of the test milks

	Appearance		Smell		Consistency		Flavor		General impression	
	week 1	week 3	week 1	week 3	week 1	week 3	week 1	week 3	week 1	week 3
Oat milk										
Women	4.8	5.3	5.6	5.6	5.7	5.3	5.1	5.7	5.6	5.7
Men	5.1	5.4	5.3	5.6	5.1	5.6	4.9	5.9	4.8	5.6
Average	5.0[b]	5.3	5.5[a, b]	5.6	5.4	5.5	5.0[a]	5.8[a]	5.2[a]	5.7[a]
(n = 24 at 1 week; n = 23 at 3 weeks)										
Soy milk	4.3[b]	3.7	4.1[b]	4.2	5.4	4.7	3.1[b]	2.9[b]	3.7[b]	3.3[b]
(n = 12 at 1 week; n = 9 at 3 weeks)										
Cow's milk	6.3[a]	5.0	6.0[a]	4.9	6.4	4.6	4.3[a, b]	4.1[a, b]	4.7[a, b]	4.0[a, b]
(n = 12 at 1 week; n = 9 at 3 weeks)										

The different parameters were evaluated on a nine-grade scale, with 1 indicating dislike very much, 5 do not like or dislike, and 9 indicating like very much. Mean values are shown.

Different superscripts within the same column indicate significant differences.

of ABTS® [2.2′-azino-di-(3-ethylbenzthiazoline sulfonate)] with metmyoglobin and H_2O_2 to produce the radical cation $ABTS^{\bullet+}$. This compound has a blue-green color, and the ability of samples to suppress the formation of $ABTS^{\bullet+}$ is measured. The results are presented as millimoles per liter using Trolox, a water-soluble α-tocopherol analogue, as standard.

Statistics

The t test for paired samples was used to compare the different dietary periods. Differences in the sensory evaluation were investigated with one-way analysis of variance and mean separation using Duncan's multiple-range test. The association between antioxidant status and the other variables was assessed by calculating the Pearson correlation coefficient. A 5% significance level was used.

Results

The sensory evaluation of the three test milks is presented in table 2. After 1 week of consumption, cow's milk got the highest score for appearance and smell, while oat milk scored higher than soya milk for flavor and for general impression. In addition, several tendencies which were not statistically significant, were observed. For example, the women were more positive to oat milk at the beginning of the trial than the men, but the men seemed to get accustomed and, after 3 weeks the scores for women and men were about the same. This explains why the total mean score for oat milk was higher at week 3 than at week 1. The scores for soya and cow's milk instead decreased during the test period, and especially soya milk got low scores after 3 weeks.

All 24 subjects completed the study successfully, but 1 of the females was excluded, since she became pregnant. There were no significant differences in body weight between baseline and 4 weeks of intake of test milks, except that the women lost weight during the soya milk period (tables 3, 4). Consumption of oat milk and cow's milk did not affect the fasting plasma glucose value, while soya milk gave a higher glucose value for the women and a lower glucose value for the men as compared with baseline values. During the test periods of oat milk and cow's milk, the insulin values

Table 3. Changes in body weight and plasma analytes for group A given oat and cow's milk (mean ± SE)

	n	Baseline	Oat milk 4 weeks	Cow's milk 4 weeks	t test
Weight, kg					
Women	5	65.4 ± 1.5	+0.5 ± 0.6	−0.3 ± 0.5	NS
Men	6	77.3 ± 3.7	+0.6 ± 0.6	+0.9 ± 0.5	NS
	11	71.9 ± 2.8	+0.5 ± 0.4	+0.4 ± 0.4	NS
Blood glucose, mmol/l					
Women	5	5.2 ± 0.1	+0.1 ± 0.1	0.0 ± 0.1	NS
Men	6	5.2 ± 0.1	+0.1 ± 0.2	+0.1 ± 0.2	NS
	11	5.2 ± 0.1	+0.1 ± 0.1	+0.1 ± 0.1	NS
Serum insulin, pmol/l					
Women	5	55 ± 6.9	+1 ± 6.0	−6 ± 8.4	NS
Men	6	60 ± 6.9	−12 ± 5.5	−8 ± 4.9	NS
	11	58 ± 4.5	−6 ± 4.3	−7 ± 4.4	NS
Total cholesterol, mmol/l					
Women	5	5.6 ± 0.4	−0.2 ± 0.2	0.0 ± 0.3	NS
Men	5	3.6 ± 0.3	−0.1 ± 0.1	0.0 ± 0.1	NS
	10	4.7 ± 0.4	−0.2 ± 0.1	0.0 ± 0.1	NS
HDL cholesterol, mmol/l					
Women	5	1.4 ± 0.1	0.0 ± 0.1	+0.1 ± 0.1	NS
Men	6	0.9 ± 0.1	+0.1 ± 0.1	+0.1 ± 0.0	p = 0.02[a]
	11	1.1 ± 0.1	+0.1 ± 0.0	+0.1 ± 0.0	p = 0.03[a]
LDL cholesterol, mmol/l					
Women	5	3.8 ± 0.3	−0.2 ± 0.2	−0.1 ± 0.3	NS
Men	5	2.5 ± 0.3	−0.1 ± 0.0	0.0 ± 0.1	p = 0.03[b]
	10	3.1 ± 0.3	−0.2 ± 0.1	−0.1 ± 0.1	NS
Triglycerides, mmol/l					
Women	5	0.9 ± 0.1	+0.1 ± 0.1	+0.1 ± 0.1	NS
Men	6	0.9 ± 0.1	−0.1 ± 0.1	−0.1 ± 0.1	NS
	11	0.9 ± 0.1	0.0 ± 0.1	0.0 ± 0.0	NS
Antioxidant status, mmol/l					
Women	5	0.92 ± 0.04	+0.01 ± 0.04	−0.02 ± 0.10	NS
Men	6	0.98 ± 0.05	+0.03 ± 0.03	0.00 ± 0.07	NS
	11	0.96 ± 0.03	+0.02 ± 0.02	−0.02 ± 0.04	NS

[a] Baseline vs. cow's milk.
[b] Baseline vs. oat milk.

Table 4. Changes in body weight and plasma analytes for group B given oat and soya milk (mean ± SE; women n = 6, men n = 6, total n = 12)

	Baseline	Oat milk 4 weeks	Soya milk 4 weeks	t test
Weight, kg				
Women	63.1 ± 2.5	−0.6 ± 0.6	−0.4 ± 0.1	p = 0.03[a]
Men	77.2 ± 2.6	+0.8 ± 0.5	+0.4 ± 0.5	NS
	70.2 ± 2.8	+0.1 ± 0.4	0.0 ± 0.0	NS
Blood glucose, mmol/l				
Women	5.3 ± 0.2	0.0 ± 0.2	+0.3 ± 0.1	p = 0.05[a]
Men	5.3 ± 0.1	0.0 ± 0.1	−0.2 ± 0.0	p = 0.04[b], 0.01[a]
	5.3 ± 0.1	0.0 ± 0.1	+0.1 ± 0.1	NS
Serum insulin, pmol/l				
Women	59 ± 5.1	−6 ± 4.6	+12 ± 14.0	NS
Men	64 ± 9.4	−3 ± 4.8	+8 ± 4.2	p = 0.03[b]
	62 ± 5.2	−5 ± 3.2	+10 ± 7.0	NS
Total cholesterol, mmol/l				
Women	5.0 ± 0.5	−0.3 ± 0.2	−0.3 ± 0.1	NS
Men	3.8 ± 0.2	−0.1 ± 0.1	−0.1 ± 0.2	NS
	4.4 ± 0.3	−0.2 ± 0.1	−0.1 ± 0.1	NS
HDL cholesterol, mmol/l				
Women	1.3 ± 0.1	0.0 ± 0.0	0.0 ± 0.0	NS
Men	1.0 ± 0.1	0.0 ± 0.0	0.0 ± 0.0	NS
	1.1 ± 0.1	0.0 ± 0.0	0.0 ± 0.0	NS
LDL cholesterol, mmol/l				
Women	3.3 ± 0.5	−0.4 ± 0.2	−0.3 ± 0.1	p = 0.03[a]
Men	2.4 ± 0.2	−0.2 ± 0.1	−0.1 ± 0.1	NS
	2.9 ± 0.3	−0.3 ± 0.1	−0.2 ± 0.1	p = 0.03[c], 0.05[a]
Triglycerides, mmol/l				
Women	0.8 ± 0.1	+0.1 ± 0.1	+0.1 ± 0.1	NS
Men	0.9 ± 0.1	+0.2 ± 0.1	+0.2 ± 0.1	NS
	0.9 ± 0.1	+0.1 ± 0.1	+0.1 ± 0.1	NS
Antioxidant status, mmol/l				
Women	0.96 ± 0.06	−0.06 ± 0.04	−0.06 ± 0.06	NS
Men	1.04 ± 0.03	−0.02 ± 0.05	−0.02 ± 0.04	NS
	1.00 ± 0.03	−0.04 ± 0.03	−0.04 ± 0.04	NS

[a] Baseline contra soya milk.
[b] Oat milk contra soya milk.
[c] Baseline contra oat milk.

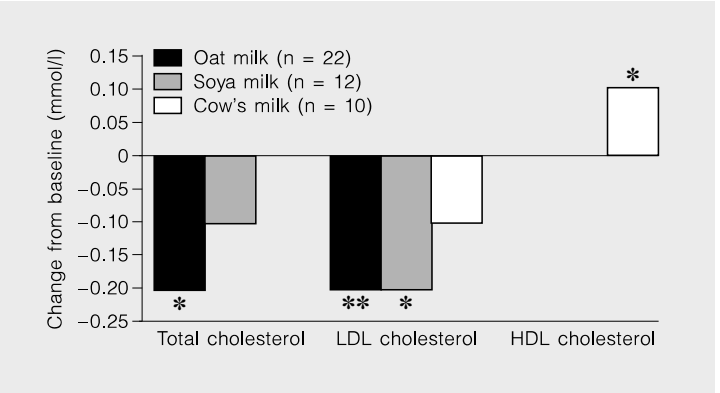

Fig. 1. Changes in plasma cholesterol values from baseline. t test: * $p < 0.05$; ** $p < 0.01$.

were nonsignificantly reduced. In contrast, there was a tendency to increased insulin values when the subjects consumed soya milk, and for the men the mean insulin value was significantly higher as compared with the mean value obtained during the oat milk period.

In the groups A and B combined, the plasma cholesterol value was significantly reduced (–0.2 mmol/l) after the consumption of oat milk for 4 weeks as compared with the baseline value (fig. 1). The reduction was more pronounced for the women who had a higher mean baseline value than the men (5.2 and 3.8 mmol/l, respectively). Cow's milk had no effect on the plasma cholesterol content, while soya milk caused a reduction (tables 3, 4, fig. 1). There were, however, no significant differences in cholesterol values between the oat milk and the cow's milk period. The oat milk and the soya milk did not affect HDL cholesterol, while cow's milk gave a significantly higher value (+0.1 mmol/l) for the men and also in the whole group. Compared with baseline values, both oat milk and soya milk resulted in a significantly lower LDL cholesterol level. For group A that consumed oat milk and cow's milk, no significant differences in LDL cholesterol between the milks were, however, observed. Plasma triglyceride values were similar after all test milks and did not differ significantly from the baseline values.

Since the three milk drinks may also differ in content of antioxidant compounds, the serum total antioxidant status was measured in the fasting state. No effect of the test milks on the serum antioxidant status was, however, observed (tables 3, 4). The mean baseline value was 0.94 mmol/l for the women and a significantly higher value, 1.01 mmol/l, was observed among men. A significant correlation between baseline antioxidant state and total plasma cholesterol was found (r = –0.56). The correlation was still significant when it was determined after controlling for age and gender. There was also a significant correlation between baseline antioxidant state and LDL cholesterol (r = –0.54), but not with HDL cholesterol, plasma triglycerides, age, and gender.

Discussion

The oat milk regimen lowered the plasma cholesterol concentration by 4% and the LDL cholesterol by 9% as compared with the baseline values. No changes in HDL cholesterol and triglyceride levels were observed. This is

in accordance with other studies indicating that intake of oats affects mainly LDL cholesterol with minimal or no effects on HDL cholesterol and triglyceride concentrations [5]. The content of dietary fiber in oat milk may be responsible for the observed LDL cholesterol lowering effect. One liter of oat milk will supply a total of 6.6 g of fiber, whereof 4.5 g is β-glucan. In the meta-analysis by Ripsin et al. [5], invention studies using 1.1–7.6 g/day of soluble fiber in oat products were included. The plasma cholesterol lowering effect was higher in studies using more than 3 g of soluble fiber than in those using lower doses. Recently the Food and Drug Administration proposed to authorize a health claim on the association between oat bran and oatmeal and reduced risk for coronary heart diseae [6]. It was stated that such foods 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 the health claim was allowed for whole oat foods, i.e., oat bran, rolled oats, and whole oat flour, providing at least 0.75 g of soluble fiber per reference amount customarily consumed [15]. This amount of soluble fiber would be provided by 0.17 liters of the oat milk used in this study.

Another mechanism behind the LDL cholesterol reducing effect could be a replacement of saturated fat and cholesterol in the customary diet when using oat milk. In one study [16] 5% of the energy intake from fat in a maintenance diet was replaced with an oat fiber extract containing 1 or 10% β-glucan. With both extracts the total and LDL cholesterol levels were significantly decreased in 23 mildly hypercholesterolemic subjects. Thus, moderate amounts of soluble fiber in combination with replacement of fat could reduce the plasma cholesterol.

The different test milks had the greatest effect for the subject that had the highest baseline plasma cholesterol values in this study. Her baseline value was 6.5 mmol/l and the level increased to 7.5 mmol/l during the cow's milk period and decreased again during the oat milk period to 6.1 mmol/l. The plasma cholesterol lowering effects of oats is usually greater in persons that have an increased plasma cholesterol level as compared with those with normal levels [17]. Plasma lipid responses seem also to be dependent on age and gender [18]. Most of the subjects in the present study were below 30 years and had already at baseline low plasma cholesterol values. This could be one reason why no significant differences in plasma lipid values between the oat and the cow's milk period could be observed. Similar results were reported by Thompson et al. [19] who gave healthy subjects cow's milk containing 2% fat (1.25 liters/day) for 3 weeks which did not lead to increased plasma cholesterol levels. Like in our study, Rossouw et al. [20] found that the HDL cholesterol value was significantly increased when full-cream cow's milk was consumed (2 liters/day) for 3 weeks.

Also soya milk gave decreased plasma cholesterol and LDL cholesterol values as compared with the baseline values. A meta-analysis of 38 studies [21] showed that a daily intake of 31–47 g soya protein significantly reduced serum cholesterol, LDL cholesterol, and triglyceride levels. The calculated daily intake of soya protein in this study was 22 g (women) and 30 g (men). The LDL cholesterol reducing effects in our study could also be related to other components in soya like the dietary fiber.

The major antioxidant defenses in serum detected by the method used were albumin (43% of the activity), urate (33), ascorbate (9), and α-tocopherol (3%) [22]. The urate concentration in serum is higher for men than for women [23], and this could be one explanation of the men's higher antioxidative capaci-

ty. There was no significant difference in antioxidative capacity related to the consumption of the different test milks. A diet with a high concentration of unsaturated fatty acids could perhaps increase the lipid peroxidation in the body. Turpeinen et al. [24] did, however, not find any differences in the concentration of lipid peroxidation products (conjugated dienes, malondialdehyde) in humans after provision of diets containing monounsaturated fatty acids (rapeseed oil based) or polyunsaturated fatty acids (sunflower oil based). In our study, the concentrations of unsaturated fatty acids were highest in oat milk and soya milk. The major antioxidant system in oats is believed to be different phenolic compounds [25]. Special phenols that have been found in oats are the avenanthramides – derivatives of caffeic and ferulic acids [26]. Other compounds with antioxidative capacity in oats and also in soya are tocols, phospholipids, pigments, amino acids, and phytic acid [27]. Maybe the antioxidants taken up into plasma from the three test milks contributed only to a so small a fraction of the total antioxidant capacity that any differences after consumption of different milks could not be detected. More specific studies on plasma antioxidants after consumption of different foods are necessary. The substantial inverse correlation of total antioxidant capacity with plasma cholesterol is a new finding. Further studies are necessary to establish whether this relation has a physiological meaning or is a reflection of the method of analysis.

In this study, we have seen that incorporation of oat milk in the diet could lead to a decreased LDL cholesterol level. One of the first recommendations to all people with an increased cholesterol concentration is a change to a diet rich in fiber and low in saturated fat [28]. Oat milk could be a useful component in such a diet, and future studies are planned to investigate this.

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References

1 Mensink RP, Katan MB: Effect of dietary fatty acids on serum lipids and lipoproteins: A meta-analysis of 27 trials. Arterioscler Thromb 1992; 12:911–919.
2 WHO Expert Committee: Prevention of Coronary Heart Disease. Technical Report Series. Geneva, World Health Organisation, 1982.
3 Anderson JW, Bridges S-R: Hypocholesterolemic effects of oat bran in humans; in Wood PJ (ed): Oat Bran. St. Paul, American Association of Cereal Chemists, 1993, pp 139–157.
4 Asp N-G, Mattsson B, Önning G: Variation in dietary fibre, β-glucan, starch, protein, fat and hull content of oats grown in Sweden 1987–1989. Eur J Clin Nutr 1991;46:31–37.
5 Ripsin CM, Keenan JM, Jacobs DR, Elmer PJ, Welch RR, Van Horn L, Liu K, Turnbull WH, Thye FW, Kestin M, Hegsted M, Davidson MH, Dugan LD, Demark-Wahnefriend W, Beling S: Oat products and lipid lowering: A meta-analysis. JAMA 1992;267:3317–3325.
6 Federal Register: Food Labelling: Health Claims; Oats and Coronary Heart Disease. 1996;61:296–337.
7 Rytter E, Erlanson-Albertsson C, Lindahl L, Lundquist I, Viberg U, Åkesson B, Öste R: Changes in plasma insulin, enterostatin and lipoproteins during an energy-restricted regimen including a new oat-based liquid food. Ann Nutr Metab 1996; 40:212–220.
8 Youngs VL: Oat lipids and lipid-related enzymes; in Webster FH (ed): Oats: Chemistry and Technology. St. Paul, American Association of Cereal Chemists, 1986, pp 205–226.

9 Sirtori CR, Lovati MR, Manzoni C, Monetti M, Pazzucconi F, Gatti E: Soy and cholesterol reduction: Clinical experience. J Nutr 1995; 125(suppl):598–605.
10 Potter SM: Overview of proposed mechanisms for the hypocholesterolemic effect of soy. J Nutr 1995; 125(suppl):606–611.
11 Artaud-Wild SM, Connor SL, Sexton G, Connor WE: Differences in coronary mortality can be explained by differences in cholesterol and saturated fat intakes in 40 countries but not in France and Finland: A paradox. Circulation 1993;88: 2771–2779.
12 McCleary BV, Codd R: Measurement of (1–3)(1–4)-β-glucan in barley and oats: A streamlined enzyme procedure. J Sci Food Agric 1991; 55:303–312.
13 Friedewald WT, Levy RJ, Fredrickson DS: Estimation of the concentration of low-density lipoprotein cholesterol in plasma, without use of the preparative ultracentrifuge. Clin Chem 1972;18:499–502.
14 Heding LA: A simplified insulin radioimmunoassay method; in Donato L, Milhaud G, Sirchis J (eds): Labelled Proteins in Tracer Studies. Brussels, Euratom, 1966, pp 345–350.
15 Federal Register: Food Labelling: Health Claims; Soluble Fiber from Whole Oats and Risk of Coronary Heart Disease. 1997;62: 15343–15344.
16 Behall KM, Scholfield DJ, Hallfrisch J: Effect of beta glucan level in oat fiber extracts on blood lipids in men and women. J Am Coll Nutr 1997;16:46–51.
17 Van Horn L, Moag-Stahlberg A, Liu KA, Ballew C, Ruth K, Hughes R, Stamler J: Effects on serum lipids of adding instant oats to usual American diets. Am J Public Health 1991; 81:183–188.
18 Keenan JM, Wenz JB, Myers S, Ripsin CM, Huang Z: Randomized controlled crossover trial of oat bran in hypercholesterolemic subjects. J Fam Pract 1991;33:600–608.
19 Thompson LU, Jenkins DJA, Vic Amer MA, Reichert R, Jenkins A, Kamulsky J: The effect of fermented and unfermented milks on serum cholesterol. Am J Clin Nutr 1982; 36:1106–1111.
20 Rossouw JE, Burger E-M, Van der Vyver P, Ferreira JJ: The effect of skim milk, yoghurt, and full cream milk on human serum lipids. Am J Clin Nutr 1981;34:351–356.
21 Anderson JW, Johnstone BM, Cook-Newell ME: Meta-analysis of the effects of soy protein intake on serum lipids. N Engl J Med 1995; 333:276–282.
22 Miller NJ, Rice-Evans C, Davies MJ, Gopinathan V, Milner A: A novel method for measuring antioxidant capacity and its application to monitoring antioxidant status in premature neonates. Clin Sci 1993; 84:407–412.
23 Fernlund P, Hanson A, Laurell C-B, Lundh B: Klinisk kemi i praktisk medicin. Studentlitteratur, Lund 1986:534–536.
24 Turpeinen AM, Alfthan G, Valsta L, Hietanen E, Salonen JT, Schunk H, Nyyssönen K, Mutanen M: Plasma and lipoprotein lipid peroxidation in humans on sunflower and rapeseed oil diets. Lipids 1995;30:485–492.
25 Collins EW: Oat phenolics: Structure, occurrence, and function; in Webster FH (ed): Oats: Chemistry and Technology. St. Paul, American Association of Cereal Chemists, 1986, pp 227–295.
26 Dimberg LH, Theander O, Lingnert H: Avenanthramides – a group of phenolic antioxidants in oats. Cereal Chem 1993;70:637–641.
27 White PJ, Xing Y: Antioxidants from cereals and legumes; in Shahidi F (ed): Natural Antioxidants: Chemistry, Health Effects, and Applications. Champaign, AOCS Press, 1997, pp 25–63.
28 National Board of Health and Welfare, Sweden: Treatment of Hyperlipidemia. Information from the Medical Department, 1989, p 5.