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ORIGINAL COMMUNICATION

Replacing cows' with sheep's dairy fat lowers plasma cholesterol concentration in participants consuming dairy fat-rich diets

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Objective: To determine the effects on plasma cholesterol concentration of replacing cows' dairy fat with sheep's dairy fat.
Design: Randomised crossover dietary intervention.
Setting: General community, Dunedin, New Zealand.
Subjects: Volunteer sample of 41 healthy adults with initial plasma cholesterol concentration between 4.8 and 7.8 mmol/l.
Interventions: Participants were asked to follow a self-selected low-fat background diet throughout the study to which, during each of the 2, 3-week dairy diets, they were asked to add sheep's or cows' dairy products.
Main outcome measures: Energy and nutrient intakes, plasma triacylglycerol fatty acids, and plasma cholesterol.
Results: Energy and nutrient intakes on the sheep-dairy and cow-dairy diets were very similar, with total, saturated, monounsaturated and polyunsaturated fat contributing 34, 18–19, 9, and 3% of total energy intake, respectively. Participants consumed approximately 50 g/day of dairy fat on each diet. Replacing cows' with sheep's dairy fat led to a 0.33 (0.11–0.56, 95% CI) mmol/l decrease (6%) in plasma total cholesterol concentration, from 5.53 (0.90, s.d.) to 5.20 (0.90) mmol/l. Plasma low-density lipoprotein (LDL) cholesterol was 0.18 (0.02–0.33) mmol/l lower on the sheep-dairy diet as was the concentration of plasma high-density lipoprotein (HDL) cholesterol, 0.11 (0.02–0.20) mmol/l. The LDL to HDL cholesterol ratio at the end of the sheep-dairy diet, 2.91 (1.10), was not significantly different ($P > 0.05$) from the cow-dairy diet, 2.73 (0.83).
Conclusions: Within the context of a diet high in dairy fat (50 g/day), replacing cows' milk fat with sheep's milk fat leads to a small reduction in plasma cholesterol concentration, but no change in the ratio of LDL to HDL cholesterol.
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Introduction

Dietary approaches to lower plasma cholesterol concentrations remain an important element of efforts to reduce population and individual risk of cardiovascular disease (Expert Panel on Detection Evaluation Treatment of High Blood Cholesterol in Adults, 2001). A central feature of cholesterol-lowering diets is a reduction in saturated fat.

Different saturated fatty acids do not all exert the same effect on plasma cholesterol. Myristic acid (C14:0), which is abundant in cows' dairy fat, is the most cholesterolaemic fatty acid followed by palmitic acid (C16:0), and lauric acid (C12:0); whereas, stearic acid (C18:0) appears to have little cholesterol-raising effect (Katan *et al*, 1995; Kris-Etherton & Yu, 1997). The effects of caprylic (C8:0) and capric (C10:0) acids are not as well documented, but have been found to be less cholesterolaemic than lauric acid (Tsai *et al*, 1999).

Sheep's (ie ewes') dairy products have been traditional foods in some Mediterranean countries (Wolff, 1995), but have only recently appeared in many other countries, such

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as New Zealand and Australia, as alternatives for the corresponding cows' products. Although the percentage of total fatty acids as saturates, monounsaturates, and polyunsaturates is similar in ewe's and cow's dairy fat, the relative amount of individual saturates differs (Iverson & Sheppard, 1989; de la Fuente *et al*, 1993; Scherz & Senser, 2000; US Department of Agriculture, 2002). Ewe's milk fat has a higher proportion of the medium chain saturates (C8:0, C10:0, and C12:0) than cows' milk fat (13% compared to 7%), and a lower proportion of palmitic (C16:0) acid (24% compared to 28%) (Scherz & Senser, 2000). In diets where a high proportion of total fat comes from dairy fat, replacing cows' with sheep's milk fat might lower plasma cholesterol concentration.

The aim of the present experiment was to ascertain whether the replacement of cows' with sheep's dairy products would produce a reduction in plasma cholesterol concentrations in a group of participants with slightly raised concentrations.

Methods

Participants were recruited by advertising in the local (Dunedin, New Zealand) newspapers. In all, 101 volunteers gave a fasting blood sample for plasma cholesterol screening. Criteria for inclusion in the study were: 18 y or older, free from chronic disease, not using medication known to affect blood lipids, fasting plasma cholesterol concentration between 4.5 and 7.8 mmol/l, and not intending to lose or gain weight during the study. In all, 53 volunteers gave written consent to participate and were enrolled in the study. Eight participants did not complete the study: two were trying to lose weight, two moved away from Dunedin, one could not adhere to the diet, and three withdrew for reasons of ill health unrelated to the study. The research project was approved by the Human Ethics Committee of the University of Otago.

Participants were asked to follow a self-selected low-fat background diet throughout the study to which, during the appropriate phases, they were asked to add sheep's dairy or cows' dairy products. The low-fat diet was followed for the first 2 weeks of the study, after which participants were randomised to the sheep-dairy or cow-dairy diets for 3 weeks, returning to the low-fat diet for 2 weeks and finishing on the alternate dairy product diet for the final 3 weeks. The purpose of the run-in low-fat diets was to accustom participants to removing the fats not permitted on the dairy diets, making it easier for them to add dairy fat into their diets without exceeding their energy requirements. A duration of 3 weeks on the dairy diets was chosen because this is long enough for the change in plasma cholesterol concentration to reach a plateau (Mensink & Katan, 1987; Hodson & Skeaff, 2002).

The low-fat diet was designed to provide 26% of total energy (%kJ) as total fat, 11–15 %kJ monounsaturated fat, 6 %kJ saturated fat, and 3 %kJ polyunsaturated fat, with a P:S ratio of 0.5. In addition to individual dietary advice, The New Zealand National Heart Foundation Food Guide booklet was given to each participant to reiterate verbal instructions. Participants were asked to choose low-fat dairy products and other foods low in saturated fat, to eat more breads, cereals, fruit, vegetables and legumes and, to limit intake of salt, alcohol and sugar. Participants were advised to avoid commercial takeaways, and high-fat dairy foods. It was recommended that all visible fat be removed from meat. Consumption of products such as margarine, butter, or oils (including foods cooked or prepared with fats) was to be kept to a minimum. Miracle Flora Light (45 g fat per 100 g) was used when necessary as a substitute for butter, margarine and other fats throughout the study. Egg consumption was limited to a maximum of three eggs per week. If hungry during the low-fat run-in periods, participants were advised to increase consumption of high-carbohydrate foods; for example, rice, pasta, bread, potato, dried fruits, tinned fruit in juice or syrup, jam, honey, marmalade, and low-fat dairy products.

The sheep-dairy and cow-dairy diets were designed to mimic the fat content of a typical New Zealand diet; that is, provide 35 %kJ total fat, 16 %kJ monounsaturated fat, 15 %kJ saturated fat, and 4–5 %kJ polyunsaturated fat, giving a P:S ratio of 0.29. Participants were advised to follow the same diet as during the run-in periods, but to consume three to six serves of dairy products per day. Guidelines for what constituted a serving were: 100–150 ml yoghurt or 25–30 g cheese. Depending on body size, physical activity, and usual energy intake, participants could choose the number of servings that was realistic and achievable for them, though they were asked to keep the number of servings during the sheep-dairy and cow-dairy diets the same.

All sheep's and some cows' dairy products were provided free to participants. Each participant was provided with the following sheep-dairy products: 3 litres sheep yoghurt, 200 g monte cristo cheese, 660 g feta, 500 g blue cheese, 900–1200 g wax-pressed cheese, and 900–1300 g pecorino romano. Extra sheep-dairy products were provided when needed. Sheep's dairy products were limited to yoghurt and cheeses because no other products were available in New Zealand during the study. For this reason, participants were asked to use reduced fat cows' milk (0.4% fat) throughout both dairy product diets. During the cow-dairy diet participants were given: 1 kg mild cheese, and a selection of either 200 g feta, 200 g brie, or 200 g blue cheese; participants were free to purchase and consume other full-fat dairy products.

Participants were asked to keep a weighed record of all the foods and beverages consumed during 2 weekdays and 1 weekend day of each dairy diet; they were free to choose which days to record. Participants were also given fridge charts to tick off the number of servings of dairy products consumed on each day.

The energy and nutrient composition of the participants' diets were calculated using computer software (Marshall,

1996) that incorporates the New Zealand Food Composition Database (Anonymous, 2000). This database contains information about the energy and nutrient composition of 1800 commonly consumed foods in New Zealand, but does not include information on sheep's dairy products. Sheep's milk composition is well described in other databases, but information on sheep's cheeses and yoghurt is lacking. We directly measured the total fat composition of all the sheep's cheeses and yoghurt used in our study (Folch *et al*, 1957); five samples of each dairy product were analysed. The remaining nutrient values were taken from other published sources of food composition (de la Fuente *et al*, 1993; Templeman & Tivey, 1997; Anonymous, 2000; Scherz & Senser, 2000; US Department of Agriculture, 2002) or imputed by assuming that the differences in composition between sheep's cheeses and milk would be similar to those between cows' cheeses and milk.

Fasting blood samples were taken from the participants on the last 2 days of the sheep-dairy and cow-dairy diets. Participants were asked to fast overnight and blood was collected by venipuncture into tubes containing disodium EDTA. Within 1 h of blood collection, plasma was separated by centrifuging blood at $2000 \times g$ for 10 min at 4°C; aliquots were removed and stored at −80°C. Participants were weighed in light clothing and height measured on the last day of each dairy diet.

Plasma total cholesterol, high-density lipoprotein (HDL) cholesterol, and triacylglycerol concentrations were measured by enzymatic test kits from Boehringer-Mannheim on a Cobas Fara II auto-analyser (Roche Diagnostics). HDL cholesterol was measured in the supernatant following precipitation of apoB-containing lipoproteins with phosphotungstate–magnesium (Assmann *et al*, 1983). Low-density lipoprotein (LDL) cholesterol concentrations were calculated using the Friedewald equation (Friedewald *et al*, 1972). One pooled plasma sample was analysed with every 16 study samples. Coefficients of variation for measurements in pooled plasma ($n = 10$) were 3.2% for total cholesterol, 4.3% for HDL cholesterol, and 4.4% for triacylglycerol. Calibration and quality control was maintained by participation in the RCPA-AACB Chemical Pathology Quality Assurance Program.

The fatty acid composition of plasma triacylglycerols was measured as described previously (Holub & Skeaff, 1987; Hodson *et al*, 2001). Briefly, the lipids from 0.2 ml of plasma was extracted and triacylglycerols separated using thin-layer chromatography (hexane:diethyl ether:glacial acetic acid, 85:15:1 by volume). Fatty acid methyl esters were prepared by acid-catalysed methanolysis and separated and quantified on an HP6890 gas chromatograph equipped with 30 m DB-225 (0.53 mm i.d.) column.

Statistical analyses were carried out using SPSS Version 10 for the Macintosh. We calculated that 38 participants were needed—using a crossover study design—to detect a 5% difference in plasma cholesterol concentration between treatments with a power of 0.90 and confidence of 0.05. This calculation assumed that our study population would have a mean plasma cholesterol concentration of 6.0 mmol/l and within-person variation of 0.4. In total 41 participants completed the study; however, a complete set of results—dietary, plasma triacylglycerol fatty acids, and plasma cholesterol—was available for 39 participants. Analysing the results for all participants or excluding those for whom a full set of results was not available made no difference to the final results or their interpretation. We report, for simplicity, the results for the 39 participants with complete data. An average of the two plasma cholesterol measurements at the end of each dairy product diet was used for each participant in the statistical analysis because the two measurements did not differ; furthermore, the coefficient of variation between the two measurements (6%) was only slightly higher than the measurement error of the cholesterol assay. Regression analysis was used to calculate the difference (95% confidence interval) between results at the end of the sheep's and cow's dairy diets. The difference between treatments was unaffected by the order of administration of the diets, therefore, results were analysed ignoring order.

Results

Results are reported for the 13 men and 26 women for whom a complete set of dietary, plasma triacyglycerol fatty acids, and plasma cholesterol data were obtained. Mean body weight at the end of the sheep-dairy and cow-dairy diets was the same (Table 1). In all, 19 participants had initial plasma cholesterol concentrations 5.2 mmol/l or higher, of whom five were above 6.5 mmol/l.

The measured fat content (g per 100 g edible portion) of the six sheep-dairy products was: blue vein, 36%; pecorino romano, 28%; wax pressed, 28%; monte cristo, 37%; feta, 32%; and yoghurt, 7%.

The energy and nutrient composition of the dairy diets, as recorded by participants in their 3-day diet records, was virtually the same, with the exception of a marginally higher proportion of total energy derived from protein during the

Table 1 Characteristics of participants

	Dairy diet	
Characteristic	*Cow*	*Sheep*
Men	13	
Women	26	
Age (y)	43 (16)	
Weight (kg)[a]	72.9 (14.2)	72.7 (13.8)
Height (m)[a]	1.70 (0.08)	1.70 (0.08)
BMI (kg/m^2)[a]	25.2 (5.4)	25.2 (4.1)

Values are reported as mean (s.d.), n=39.
[a]Measured at the end of each diet.

sheep-dairy diet. The percentage of total dietary energy that participants obtained as fat met the targets set in the design of the diets (35 %kJ); however, the target for saturated fat (15 %kJ) was exceeded (Table 2).

Total dairy fat (Table 3) intake was approximately the same on each diet, accounting for 60 and 54% of total fat intake on the sheep-dairy and cow-dairy diets, respectively. Participants ate 128 g of sheep's cheeses and 115 g of cows' cheeses. The proportion of total dairy fat derived from cheeses was 75% on the sheep-dairy diet and 80% on the cow-dairy diet. Yoghurt intake was 79 g higher during the sheep-dairy than cow-dairy diet. Statistical comparison of dairy product consumption between the diet groups was not possible because the computer software we used to analyse the diet records only calculates a mean intake for all participants on each diet.

At the end of the sheep-dairy diet, myristic (C14:0), palmitic (C16:0), and myristoleic (C14:1) acids were significantly lower and linoleic acid (C18:2n-6) significantly higher than at the end of the cow-dairy diet, although the magnitude of the differences in fatty acid composition were small. In general, the fatty acid composition of plasma triacylglycerol in our study was similar to that in participants of other studies where dairy products were the major sources of fat (Cox *et al*, 1995; Hodson *et al*, 2001). All three long-chain n-3 polyunsaturated fatty acids (C20:5n-3, C22:5n-3, and C22:6n-3) were significantly higher after the sheep dairy diet, though the magnitude of the difference was small. Alpha-linolenic acid in plasma triacylglycerol was also higher during the sheep-dairy diet, though the confidence interval of the difference just overlapped with zero (Table 4).

Plasma total and LDL cholesterol concentrations were significantly lower at the end of the sheep-dairy diet than at the end of the cow-dairy diet; by 6 and 5%, respectively. HDL cholesterol concentration was also lower at the end of the sheep-dairy diet, so that the ratio of LDL to HDL cholesterol was not significantly different at the end of the two dairy diets. We found no significant correlation ($r=0.167$, $P=0.310$) between initial plasma cholesterol concentration and the change in plasma cholesterol between the sheep's and cows' diary diets (Table 5).

Discussion

The major finding of our study was that sheep's dairy products were less cholesterolaemic than cows' dairy products. Mean plasma cholesterol concentration was reduced by 6% when participants with slightly raised cholesterol concentrations replaced approximately 50 g of cows' dairy fat with an equivalent amount of sheep's dairy fat. To our knowledge, the present study is the first report of the effect of sheep's dairy products on plasma cholesterol concentrations. The randomised, crossover design of the study adds considerably to the confidence in the main finding because the plasma cholesterol concentrations were compared, for all participants, at end of each dairy product diet and there was no evidence that the order of diet administration affected the results. Furthermore, the measures of dietary intake—the daily checklist of dairy products, the 3-day diet records, and the fatty acid composition of plasma triacylglycerols—indicated a high level of participant compliance to the study diets, suggesting that the two dairy diets differed only in the animal source of the dairy products.

Both cows' and sheep's dairy fat are rich in saturated fat and have a similar proportion of myristic acid (C14:0), but the relative proportion of short and medium chain saturates

Table 2 Energy and nutrient intake during the study

	Dairy diet		
Constituent	*Cow*[a]	*Sheep*[a]	*Difference (95% CI)*[b]
Energy (kJ)	9686 (2233)	9194 (1939)	−492 (−1446, 461)
Carbohydrate (%kJ)	44 (8)	42 (7)	−2 (−5, 2)
Protein (%kJ)	18 (3)	19 (3)	1 (0, 3)
Total fat (%kJ)	34 (7)	34 (7)	0 (−3, 3)
Saturated (%kJ)	18 (4)	19 (5)	1 (−1, 3)
Monounsaturated (%kJ)	9 (2)	9 (2)	0 (−1, 1)
Polyunsaturated (%kJ)	3 (1)	3 (1)	0 (0, 1)[c]
–P:S ratio[d]	0.18 (0.08)	0.19 (0.09)	0.02 (−0.02, 0.05)
Cholesterol (mg)	282 (110)	326 (115)	44 (−8, 95)
Dietary fibre (g)	23 (6)	25 (7)	2 (−1, 5)
Alcohol (g)	6 (8)	8 (11)	2 (−2, 5)
Calcium (mg)	1715 (597)	1609 (479)	−106 (−351, 140)
Alcohol (%kJ)	2 (3)	2 (3)	0 (−1, 2)

%kJ=percent of total energy.
[a]Values are reported as mean (s.d.).
[b]Sheep-dairy minus cow-dairy.
[c]Confidence interval includes zero.
[d]P:S=polyunsaturated to saturated fat.

Table 3 Daily consumption of dairy products[a]

Foods eaten	*Weight (g)*	*Energy (kJ)*	*Total fat (g)*
Cows' dairy products			
Cheeses			
Blue vein	5	80	2
Camembert	8	91	2
Cheddar, epicure	4	65	1
Cheddar, mild	68	1204	24
Colby	11	189	4
Cottage cheese	0	2	0
Cream cheese	2	34	1
Edam	8	111	2
Feta	7	77	1
Gouda	1	12	0
Gruyere	0	4	10
Parmesan	1	2	0
Swiss	0	1	0
Sour cream	3	23	1
Cream	10	165	4
Frozen confectionary	1	9	0
Ice cream	27	234	3
Yoghurt	101	363	2
Trim milk	188	326	1
Total	446	3008	48
Sheep's dairy products			
Cheeses			
Blue vein	17	166	6
Feta	29	417	9
Monte cristo	7	121	2
Pecorino romano	27	489	8
Wax pressed	48	698	13
Yoghurt	180	811	13
Trim milk (cows)	165	286	0
Total	473	2988	52

[a]Based on three-day diet records.

Table 4 Fatty acid composition of plasma triacylglycerol (mol%)

	Dairy diet		
Fatty acid	*Cow*[a]	*Sheep*[a]	*Difference (95% CI)*[b]
C12:0	0.37 (0.23)	0.35 (0.18)	−0.02 (−0.10, 0.05)
C14:0	3.40 (1.15)	3.11 (0.89)[c]	−0.30 (−0.60, 0.00)
C14:1	0.41 (0.20)	0.29 (0.14)[c]	−0.12 (−0.16, −0.07)
C15:0	0.57 (0.16)	0.58 (0.15)	0.01 (−0.05, 0.08)
C16:0	28.46 (3.63)	27.13 (2.85)[c]	−1.34 (−2.21, −0.47)
C16:1	6.20 (1.68)	6.16 (1.75)	−0.04 (−0.40, 0.32)
C17:0	0.41 (0.12)	0.42 (0.12)	0.01 (−0.04, 0.07)
C18:0	3.75 (1.06)	3.73 (1.11)	−0.02 (−0.40, 0.35)
C18:1	37.83 (3.53)	37.90 (3.51)	0.07 (−0.90, 1.03)
C18:2n-6	12.81 (3.87)	13.97 (3.03)[c]	1.16 (0.17, 2.14)
C18:3n-6	0.51 (0.20)	0.49 (0.18)	−0.02 (−0.08, 0.04)
C18:3n-3	1.22 (0.30)	1.35 (0.47)	0.13 (−0.01, 0.27)
C20:4n-6	1.05 (0.27)	1.07 (0.25)	0.02 (−0.05, 0.10)
C20:5n-3	0.33 (0.08)	0.40 (0.21)[c]	0.07 (0.01, 0.13)
C22:5n-3	0.47 (0.13)	0.53 (0.16)[c]	0.06 (0.02, 0.10)
C22:6n-3	0.68 (0.22)	0.85 (0.57)[c]	0.18 (0.02, 0.33)

[a]Values are reported as mean (s.d.), n=39.
[b]Sheep-dairy minus cow-dairy diet.
[c]$P<0.05$, different from cow-dairy diet.

is higher and palmitic acid (C16:0) lower in sheep's than in cows' fat (de la Fuente *et al*, 1993; Templeman & Tivey, 1997; 2000; US Department of Agriculture, 2002). The differences in fatty acid composition of the two types of dairy fat must, to some extent, account for the lower plasma cholesterol concentrations during the sheep-dairy diet because, on the balance of evidence, medium chain fatty acids are less cholesterolaemic than their longer chain counterparts, notably myristic (C14:0) and palmitic acids (C16:0) (Katan *et al*, 1995; Kris-Etherton & Yu, 1997). Cox *et al* (1995) reported that plasma total cholesterol concentration decreased by 6% (0.4 mmol/l) when the predominant source of fat in the diet was changed from butter fat, rich in palmitic (C16:0) and myristic (C14:0) acids, to coconut oil, which contains roughly 45% of the total fatty acids as lauric acid (C12:0). In that study, total saturated fat (20% of energy) and myristic acid (C14:0) intakes (7–8% of total fat) were similar on the butter and coconut diets, the major dietary difference being the substitution of lauric acid (C12:0) on the coconut diet for palmitic acid on the butter diet. In another study (Denke & Grundy, 1992), plasma cholesterol concentration was 4% (0.23 mmol/l) lower in men consuming liquid-formula diets in which lauric acid (C12:0) replaced palmitic acid (C16:0). In contrast to these two studies, Temme *et al* (1996) reported that participants who ate lauric (C12:0) acid-rich diets had higher plasma cholesterol concentrations than when they consumed diets rich in palmitic acid (C16:0). However, the higher plasma cholesterol concentrations during the laurate-rich (C12:0) diet cannot be attributed solely to lauric acid (C12:0) because there was more myristic acid (C14:0) in the laurate-rich diet. Caprylic acid (C8:0) and capric acid (C10:0), which are both higher in sheep's than cows' milk fat, have been found to be less cholesterolaemic than lauric acid (C12:0). In a small, but well-designed, crossover trial, Tsai *et al* (1999) reported that plasma total cholesterol concentration was reduced by 8% (0.37 mmol/l) when women replaced 30 g of lauric acid (C12:0) with a mixture of caprylic (C8:0) and capric (C10:0) acids.

There does not appear to be a strong effect on plasma HDL of substituting medium chain fatty acids for myristic (C14:0) and palmitic (C16:0) acids (Denke & Grundy, 1992; Cox *et al*, 1995; Temme *et al*, 1996; Tsai *et al*, 1999); however, participants in the present study had significantly lower HDL cholesterol concentrations when consuming the sheep's dairy products. Thus, the favourable improvement in lipoprotein-mediated cardiovascular risk associated with the lowering of total and LDL cholesterol during the sheep-dairy diet was offset, somewhat, by the reduction in HDL cholesterol.

The changes in fatty acid composition of plasma triacylglycerol, although relatively small, were consistent with the lower plasma cholesterol concentration during the sheep-

Table 5 Plasma lipid concentrations

	Dairy diet		
Plasma lipid	*Cow*[a]	*Sheep*[b]	*Difference (95% CI)*[b]
Total cholesterol (mmol/l)	5.53 (0.90)	5.20 (0.90)[c]	−0.33 (−0.56, −0.11)
HDL cholesterol (mmol/l)	1.37 (0.32)	1.26 (0.37)[c]	−0.11 (−0.20, −0.01)
LDL cholesterol (mmol/l)	3.56 (0.75)	3.38 (0.75)[c]	−0.18 (−0.33, −0.02)
Triacylglycerol (mmol/l)	1.32 (0.47)	1.21 (0.34)	−0.11 (−0.24, 0.02)
LDL/HDL cholesterol ratio	2.73 (0.83)	2.91 (1.10)	0.17 (−0.11,0.45)

[a]Values are reported as mean (s.d.), n=39.
[b]Sheep-dairy minus cow-dairy diet.
[c]$P<0.05$, different from cow-dairy diet.

dairy diet. Myristic (C14:0) and palmitic (C16:0) acids were lower and linoleic acid (C18:2n-6) was higher in plasma triacylglycerol during the sheep-dairy diet; however, lauric acid (C12:0) was not different. Lauric acid (C12:0) constitutes less than half a percent of total plasma triacylglycerol fatty acids (Denke & Grundy, 1992; Cox *et al*, 1995) and the slightly lower lauric acid (C12:0) content of sheep's milk fat may not have differed enough from cows' milk fat to cause a change in the level of this fatty acid in plasma triacylglycerol. Capric acid (C10:0), on the other hand, is almost three times higher (percent of total fatty acids) in sheep's milk than cows' milk fat; however, the concentration of this fatty acid in plasma triacylglycerol was too low to be detected.

We cannot exclude the possibility that the diets participants actually ate differed from reported intake, in a way that affected the plasma fatty acid and cholesterol results. We analysed the total fat content of the sheep's dairy products used in our study and are confident that total dairy fat intake on the two dairy diets was similar or, if anything, marginally higher during the sheep-dairy diet. A higher dairy fat intake during the sheep-dairy diet would tend to attenuate rather than exaggerate the difference in plasma cholesterol concentrations at the end of the two dairy diets (Clarke *et al*, 1997). Moreover, it is unlikely that systematic under or over-reporting of foods containing fat would occur only during the sheep-dairy diet. The diets were administered in random order and we found no evidence that the difference in plasma cholesterol concentration between the two dairy diets was affected by the order in which the participants were asked to follow them.

The small, but statistically significant, increases in the long chain n-3 polyunsaturated fatty acids (C20:5n-3, C22:5n-3, and C22:6n-3) in plasma triacylglycerol during the sheep diet were unexpected. Sheep milk contains negligible amounts of these fatty acids and the alpha-linolenic acid (C18:3n-3) content, although higher in sheep's than cows' milk fat, is low (around 1–2% of total fatty acids) (de la Fuente *et al*, 1993; Scherz & Senser, 2000; US Department of Agriculture, 2002; Wojtowski *et al*, 2002). The 50 g of sheep's dairy fat would have provided, at most, an additional 0.5 g per day of alpha-linolenic acid—the precursor fatty acid to the long chain n-3 polyunsaturated fatty acids. Ingestion of substantially larger amounts of alpha-linolenic acid (9 g per day for 4 week) increased C20:5n-3 and C22:5n-3 in plasma triacylglycerol (by 0.3 and 0.5% of total fatty acids, respectively); however, 22:6n-3 remained unchanged (Cunnane *et al*, 1995). The complete lack of change in blood levels of 22:6n-3 with ingestion of alpha-linolenic acid is a consistent finding of feeding trials lasting less than several months (Chan *et al*, 1993; Li *et al*, 1999) and argues that some of the participants in our study ate more fish—a source of all three preformed long chain n-3 polyunsaturated fats—during the sheep diet. The combination of increased alpha-linolenic acid from the sheep-dairy products and increased fish intake could explain the fatty acid results. It is important to emphasise that the magnitudes of the changes in n-3 polyunsaturated fatty acids in plasma triacylglycerol were small and that long chain n-3 polyunsaturated fatty acids have little material effect on plasma total and LDL cholesterol concentrations (Harris, 1997).

Participants ate more yoghurt during the sheep's than cows' dairy diets (180 g compared with 101 g) because cheeses and yoghurt were the only dairy products that participants could choose from during the sheep's dairy diet. Cows' milk fermented with a specific bacterial culture (Causidio®) has been found to reduce plasma cholesterol concentrations by 4% (0.22 mmol/l) in comparison with acidified milk fermented with an organic acid (Agerholm-Larsen *et al*, 2000). However, in general, the cholesterol-lowering effects of fermented compared with nonfermented dairy products are equivocal (St-Onge *et al*, 2000). In those studies where a cholesterol-lowering effect of yoghurt has been reported, the amount of yoghurt consumed was between 200 and 500 ml per day. Therefore, it is unlikely that the higher consumption of yoghurt (80 g) during the sheeps diets accounted for any more than a small proportion of the difference in plasma cholesterol concentration between the two diets.

Several investigators have examined the effects on plasma cholesterol of modified butter-fat, produced by manipulating bovine feed (Noakes *et al*, 1996; Tholstrup *et al*, 1998; Poppitt *et al*, 2002). Although results from a recent metabolic

ward study (Poppitt *et al*, 2002) indicate a favourable reduction in total and LDL cholesterol concentrations when modified butter fat (70 g/day) replaced regular butter fat, the high cost of producing these butters remains a hindrance to their commercial availability. On the other hand, the fatty acid composition differences between sheep's and cows' dairy fat occur naturally and milk production costs are only slightly higher for sheep. Participants in our study consumed a large amount of dairy fat; more than is typical, even in countries where dairy product consumption is high. This was done to examine the maximum potential effect of substituting sheep's dairy fat for cows' dairy fat on blood cholesterol. In diets where smaller amounts of dairy fat are substituted and in which other food sources of fat predominate the effects on blood cholesterol are likely to be attenuated. Furthermore, in diets where the goal is to achieve a maximum lowering of plasma cholesterol concentrations, reducing intake of all saturated fats would be preferable to substituting saturated fat from sheep's dairy products for cows' dairy products.

The results of our study indicate that sheep's dairy products are less cholesterolaemic than cows' dairy products and, in this regard, are a reasonable animal fat substitute for cows' dairy products.

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