EFFECTS OF FAT-RICH OIL CAKES ON CHEESE FATTY ACID COMPOSITION, AND ON CHEESE QUALITY

Konstantin Mihhejev, Merike Henno, Meelis Ots, Eve Rihma, Priit Elias, Sirje Kuusik, Olav Kärt
Department of Animal Nutrition and Animal Products Quality,
Institute of Veterinary Medicine and Animal Sciences, Estonian University of Life Sciences,
Kreutzwaldi 46, 51006 Tartu, Estonia, tel. +372 7 313 471; e-mail: konstantin.mihhejev@emu.ee

Summary. Feeding fat to dairy cattle has been described frequently as an appropriate means to improve the favourable fatty acid (CLA) content of milk products, especially that of cheese. The objective of this study was to determine the effect of fat-rich oil cakes used in Estonia on milk and cheese quality. The experiment was conducted with Estonian Holstein dairy cows according to 4×4 Latin square design. The cows were fed *ad libitum* grass silage, 8 kg concentrate consisting of barley and oat meal, soybean meal and cold pressed oil cakes as fat sources (0.5 kg crude fat per animal per day) – rapeseed (RC), linseed (LC), gold of pleasure (*Camelina sativa*) cake (GP) and soybean meal (SBM) as the non-fat control variant – and a mineral-vitamin supplement. The inclusion of fat-rich cakes in the diet affected the overall fatty acid composition of cheese. Diets rich in unsaturated fats increased long-chain unsaturated fatty acids in milk and cheese fat, CLA included. Processing the milk into cheese did not alter the overall fatty acid profile. The dietary source of fat had a significant effect ($P<0.05$) on milk coagulation time and curd firmness. There were no significant effects on the experimental cheese estimates of dry matter and fat, or on the fat content in dry matter. Fat source had a slight effect on the overall quality score and texture/colour parameter of the experimental cheese ($P<0.05$). The quality score for fat source tended to decrease as follows: LC>SBM>RC>GP. The taste panelists found no flavour and no taste differences in cheese among treatments (except between LC and GP), although the presence of specific flavour (above perceptible level) was much higher in GP than in other treatments. The experimental results suggest that fat supplementation affects cheese fatty acid composition, milk coagulation parameters and cheese quality properties, depending on the degree of saturation the fat supplement.

Key words: dairy cattle, fat supplementation, cheese quality, fatty acid.

DAUG RIEBALŲ TURINČIŲ IŠSPAUDŲ ĮTAKA RIEBIŲJŲ RŪGŠČIŲ KIEKIUI PIENE IR SŪRYJE BEI SŪRIŲ KOKYBEI

Konstantin Mihhejev, Merike Henno, Meelis Ots, Eve Rihma, Priit Elias, Sirje Kuusik, Olav Kärt
Gyvulių mitybos ir gyvūnų produktų kokybės katedra, Veterinarinės medicinos ir gyvulininkystės institutas,
Estijos gyvulininkystės universitetas, Kreutzwaldi 46, 51006 Tartu, Estija;
tel. +372 731 3471; el. paštas: konstantin.mihhejev@emu.ee

Santrauka. Melžiamų karvių šėrimas riebalais dažnai taikomas kaip priemonė pagerinti riebiųjų rūgščių kiekį (RRK) pieno produktuose, ypač sūryje. Šio tyrimo tikslas buvo nustatyti daug riebalų turinčių išspaudų, naudojamų Estijoje, įtaką pieno ir sūrio kokybei. Eksperimentas atliktas su Holšteino veislės melžiamomis karvėmis Lotynų kvadrato 4×4 metodu. Karvės buvo *ad libitum* šeriamos žolės silosu, 8 kg koncentratų, susidedančių iš miežinių ir avižinių miltų, sojų miltų ir šaltai spaustų riebalingų išspaudų, panaudotų kaip riebalų šaltinis (0,5 kg žalių riebalų karvei per parą), – rapsų sėklos (RS), linų sėklos (LS), rapsų (*Camelina sativa*) išspaudos (RI) ir kaip kontrolė sojų miltai (SM) be riebalų bei vitaminų-mineralų papildas. Daug riebalų turinčios išspaudos racione darė įtaką riebiųjų rūgščių sudėčiai sūryje. Racionai, turintys daug nesočiųjų riebiųjų rūgščių, padidino didelio molekulinio svorio nesočiųjų riebiųjų rūgščių kiekį pieno ir sūrio riebaluose, taip pat ir RR kiekį. Pieno perdirbimas į sūrį neturėjo įtakos riebiųjų rūgščių profiliui. Riebalų šaltinis racione taip pat neturėjo didelės įtakos ($p<0,05$) pieno sutraukinimo laikui ir sutraukos tvirtumui. Sūrio sausosios medžiagos ir riebalų kiekiui, taip pat riebalų kiekiui sausojoje medžiagoje įtaka buvo nedidelė. Riebalų šaltinis darė nedidelę įtaką bendriems sūrio, pagaminto iš eksperimentinės grupės pieno ($p<0,05$), kokybės ir struktūros/spalvos parametrams. Su riebalų šaltiniu susiję kokybės parametrai pablogėjo: LS>SM>RS>RI. Degustatoriai nepastebėjo kvapo ar skonio skirtumo tarp skirtingų bandymų sūrių (išskyrus tarp LC ir GP), nors specifinis kvapas (viršijantis suvokimo lygį) buvo labiau juntamas panaudojus RI. Eksperimento duomenys leidžia daryti išvadą, kad riebalų priedas turėjo įtakos sūrio riebiųjų rūgščių sudėčiai, pieno sutraukinimo rodikliams ir sūrio savybėms, susijusioms su riebalų prisotinimo laipsniu pašariniuose prieduose.

Raktažodžiai: melžiamos karvės, riebaliniai papildai, sūrio kokybė, riebiosios rūgštys.

Introduction. Healthy nutrition plays an important role in human health. Lipids are the third main class of macronutrients needed in human nutrition. Fats are important in controlling energy reserves of the human organism, and transporting other nutrients such as "fat-soluble vitamins". They are also an essential component of the cell membrane, and internal fatty tissues protect the vital organs from trauma and temperature change (Kokassaar et al., 1999). Saturated fatty acids originate primarily from foods of animal origin, having a strong effect on increasing low-density lipoprotein (LDL) or the "bad cholesterol" in the blood (Roche et al., 2001).

Polyunsaturated fatty acids are under investigation by many research groups. Linoleic and linolenic acids are essential fatty acids needed biochemically by the human organism. Essential fatty acids are important for normal growth, especially of the blood vessels and nerves. CLA may have a potential therapeutic effect on prevention of many common diseases, including cardiovascular disease, and some forms of cancer; in reducing adipose tissue mass and increasing lean mass (Roche et al., 2001; Dhiman et al., 2005).

A limited number of studies have dealt with the effect of CLA enrichment of milk on the production of cheese. Dhiman et al. (1999) reported that extruded cottonseed and soybeans in the diets of dairy cows resulted in an increase of CLA content in milk which could be used in the successful manufacture of Mozzarella cheese, although the physical or sensory attributes of the CLA-enriched cheese were not evaluated. Enrichment of CLA in raw milk from dietary fish oil (Avramis et al., 2003), mixtures of fish and sunflower oil (Jones et al., 2005), and rapeseed oil (Ryhänen et al., 2005) has not shown a significant negative effect on the overall impression and flavour characteristics of Cheddar and Edam types of cheese. An increase in the oxidized flavour of cheese may reflect the increased level of unsaturated FA in the milk from cows supplemented with a diet rich in unsaturated fats (Allred et al., 2006).

The present study was designed to investigate the organoleptic and physical properties of cheese, and the fatty acid composition of cheese made from the modified milk of cows that had been fed fat-rich supplement (cakes) from oil cultivars grown in Estonia. The novelty of this experiment involves as assessment of the different aspects of the effect of C*amelina sativa* cake on fatty acid concentration and the overall quality of cheese that have never before been studied in Estonia. As *Camelina sativa* cake contains a high concentration of long-chain unsaturated fatty acids, it is very similar to fish oil fatty acid spectrum (Rossell, 1989; AbuGhazaleh et al., 2002).

Materials and Methods. Four experimental Estonian Holstein dairy cows of (mean±SE) 628±28 kg live weight, averaging 110±9 DIM were used in a 4×4 Latin square design. Duration of the preliminary period was 2 weeks and that of the experimental period 4 days. The daily rations were fed individually in equal-sized meals at 06:00 and 16:00h. The cows had continuous access to water and were milked daily *in situ* at approximately 03:30 and 14:30h. The diets were based on *ad libitum* grass silage, mineral feed, 8 kg of concentrates prepared from barley and oat meal, soybean meal and cold pressed oil cakes as fat sources (0.5 kg crude fat per animal per day): rapeseed (RC), linseed (LC), gold of pleasure (*Camelina sativa*) cake (GP) and soybean meal (SBM) as a non-fat control variant.

Milk samples were collected daily on four consecutive days of the experimental period. One part of the sample was preserved with Bronopol® while the other part was frozen. Milk samples preserved with Bronopol® were analysed for fat, protein and lactose content by infrared analysis (Milk Analyser System 4000, Foss Electric, HillerØd, Denmark) at the Estonian Animal Recording Centre. Casein concentration was determined by using the Kjeldahl method. Milk renneting properties (renneting time and curd firmness) were determined by an Optigraph® 30min after the addition of a clotting ferment (Milase MRS, 750 IMCU/ml, CSK Food Enrichment B.V., Leeuwarden, The Netherlands) according to Kübarsepp et al. (2005) in the milk quality laboratory of the Institute of Veterinary Medicine and Animal Sciences of the Estonian University of Life Sciences. The frozen milk samples were analysed for milk fatty acid composition. The chemical composition and the fatty acid structure of the milk from the cows receiving control and experimental diets are shown in Table 1.

For cheese preparation, 10 litres of milk was taken from each cow on the last day of each experimental period. Edam type cheese was prepared with FT20-MkII cheese vat. Milk was incubated at 34°C with a starter culture Visby 505 (2 v/w) and stirred continuously during 24.4 minutes until the milk pH was approximately 6.48. Single strength rennet (DSM Fromase 2200 TL) was mixed into the milk at the level of 0.0034% (v/w). The cheese was packed in film, matured at 12°C for 5-6 weeks and analysed for fatty acid composition. Cheeses were sampled for composition analysis and analyzed for fat and moisture contents using IDF methods 152A:1997 and 4A:1982 respectively. Taste, flavour, body and texture of Edam cheese were evaluated on a five-point scale (1=very poor; 5=excellent) by ten non-trained panelists of the Institute of Animal Sciences at the Estonian University of Life Sciences according to the reference method (EV ST 616-92).

For determining the composition of fatty acids in milk and cheese fat, the fat was extracted according to the international standard ISO 14156 / IDF 172:2001. Fatty acid methyl esters were prepared according to the method proposed by Christie (1982) and Chouinard et al. (1999); the fatty acid profile was analysed by gas chromatography (Agilent 6890, Agilent Technologies Inc, USA).

The effect of treatment, individual cow and period on cheese compositional parameters and fatty acids content were assessed with the following mixed linear model of fixed effects (SAS Institute, 2004):

$Y_{ijk} = \mu + T_i + P_j + C_k + E_{ijk}$,

where Y_{ijk} = cheese composition traits; μ - the overall mean; i - the response for the treatment (i=1-4); j - fixed effect of cow (j=1-4); k - fixed effect of period (k=1-4) and E_{ijk} - the random residual error. The least significant difference at $P<0.05$ was used to determine significant differences among the least square means. Model effects were considered significant at $P<0.05$.

Results and Discussions.

Milk casein content, renneting properties and pH. Milk casein percentage response to fat supplementation was significant ($P<0.05$); it was relatively low for LC and RC treatments compared to SBM and GP diets (Table 2). This agrees with earlier reports that fat sources in dairy cow diets result in a decrease in milk protein and casein concentrations (DePeters and Cant, 1992; Madison-Anderson et al., 1997; Dhiman et al., 1999).

Table 1. **Mean values of milk yield, compositional parameters and fatty acid composition of milk used for cheese making**

Traits	Treatment[1]			
	SBM	RC	LC	GP
Milk yield, kg/day	23.7	26.8	26.7	20.9
Fat, %	3.95	4.15	3.70	3.27
Protein, %	3.13	3.01	2.89	3.03
Lactose, %	4.75	4.70	4.71	4.72
Milk fatty acid composition, g/100 g total fatty acids				
C4:0	4.72	4.51	4.94	4.09
C6:0	2.44	2.09	2.34	1.87
C8:0	1.21	0.98	1.12	0.91
C10:0	2.66	1.97	2.22	1.87
C12:0	2.94	2.16	2.39	2.18
C14:0	11.63	9.51	9.76	9.09
C14:1 t-9	nd	nd	nd	0.02
C14:1 c-9	1.04	0.87	0.73	1.15
C15:0	0.99	0.84	0.87	0.96
C15:0 c-10	0.34	0.27	0.26	0.23
C16:0	32.12	22.15	23.19	21.01
C16:1 t-9	0.06	0.08	0.08	0.50
C16:1 c-9	1.40	1.03	0.80	1.50
C17:0	0.46	0.39	0.41	0.42
C17:1 c-10	0.18	0.16	0.14	0.19
C18:0	9.88	13.63	14.25	4.75
C18:1 t-6…t-8	0.29	0.78	0.37	1.00
C18:1 t-9	0.20	0.49	0.27	0.86
C18:1 t-10	0.32	0.72	0.36	1.21
C18:1 t-11	1.12	1.47	1.78	8.29
C18:1 c-9	18.41	26.88	22.68	15.15
C18:1 c-11	0,48	0.99	0.77	1.25
C18:2 t-11, c-15	0.12	0.12	0.62	2.51
C18:2 c-9, c-12 n6	1.08	1.15	1.16	1.23
C18:2 c-9, t-11 (CLA)	0.64	0.87	0.93	4.96
C18:2 t-10, c-12 (CLA)	nd	nd	nd	0.01
C18:3 c-9, c-12, c-15 n3	0.39	0.42	0.99	0.59
C19:0	0.05	0.05	0.09	0.10
C20:0	0.17	0.26	0.17	0.37
C20:1 c-11	0.52	0.62	0.74	1.67
C20:5 n3	0.04	0.05	0.04	0.19
Other	4.11	4.49	5.52	9.87
Σ $C_4 – C_{10}$	11.04	9.55	10.63	8.74
Σ $C_{12} – C_{16}$	50.52	36.91	38.07	36.64
Σ Saturated[2]	69.27	58.54	61.76	47.61
Σ Unsaturated[3]	26.62	36.97	32.72	42.52
Σ Monounsaturated[4]	24.36	34.35	28.98	33.04
Σ Polyunsaturated[5]	2.26	2.62	3.75	9.48
Σ CLA[6]	0.64	0.87	0.93	4.97

[1] – Fat source: SBM- soybean meal, RC- rapeseed cake, LC-linseed cake, GP-gold of pleasure cake
[2] – $C_{4:0}$, $C_{6:0}$, $C_{8:0}$, $C_{10:0}$, $C_{12:0}$, $C_{14:0}$, $C_{15:0,}$ $C_{16:0}$, $C_{17:0}$, $C_{18:0}$, $C_{19:0}$, $C_{20:0}$.
[3] – $C_{14:1\ t\text{-}9}$, $C_{14:1\ c\text{-}9}$, $C_{16:1\ t\text{-}9}$, $C_{16:1\ c\text{-}9}$, $C_{18:1\ t\text{-}6,7,8}$, $C_{18:1\ t\text{-}9}$, $C_{18:1\ t\text{-}10}$, $C_{18:1\ t\text{-}11}$, $C_{18:1\ c\text{-}9}$, $C_{18:1\ c\text{-}11}$, $C_{18:2\ t\text{-}10,\ c\text{-}12\ (CLA)}$, $C_{18:2\ t\text{-}11,\ c\text{-}15}$, $C_{18:2\ c\text{-}9,\ t\text{-}11\ (CLA)}$, $C_{18:2\ c\text{-}9,\ c\text{-}12\ n6}$, $C_{18:3\ c\text{-}9,\ c\text{-}12,\ c\text{-}15\ n\text{-}3}$, $C_{20:1}$, $C_{20:5\ n3\ (EPA)}$.
[4] – $C_{14:1\ t\text{-}9}$, $C_{14:1\ c\text{-}9}$, $C_{16:1\ t\text{-}9}$, $C_{16:1\ c\text{-}9}$, $C_{18:1\ t\text{-}6,7,8}$, $C_{18:1\ t\text{-}9}$, $C_{18:1\ t\text{-}10}$, $C_{18:1\ t\text{-}11}$, $C_{18:1\ c\text{-}9}$, $C_{18:1\ c\text{-}11}$, $C_{20:1\ c\text{-}11}$.
[5] – $C_{18:2\ t\text{-}10,\ c\text{-}12\ (CLA)}$, $C_{18:2\ t\text{-}11,\ c\text{-}15}$, $C_{18:2\ c\text{-}9,\ t\text{-}11\ (CLA)}$, $C_{18:2\ c\text{-}9,\ c\text{-}12\ n6}$, $C_{18:3\ c\text{-}9,\ c\text{-}12,\ c\text{-}15\ n3}$, $C_{20:5\ n3\ (EPA)}$.
[6] – $C_{18:2\ c\text{-}9,\ t\text{-}11}$, $C_{18:2\ t\text{-}10,\ c\text{-}12}$.

The observed increase in milk casein content by GP treatment (2.82%) can be partially explained by a large fall in milk production (dilution effect) − 20.9 day/kg (Table 1) − rather than a direct negative effect of fat. A slight tendency for lower milk casein content in milk often causes increase in the whey protein and NPN fractions (Coppock and Wilks, 1991). Although supplementary fat tends to depress casein percentage through a dilution effect in the milk, some studies confirmed somewhat different hypotheses. The results suggested that including fat in the diet depressed casein content in milk through modified (slowed) synthesis of microbial protein in the rumen (Coppock and Wilks, 1991) and reducing mammary blood flow rate (Cant et al., 1993). In contrast, Bell and Kennelly (2003) observed contrary results in casein concentration by direct infusion in the duodenum of the cow 150g/CLA. The author speculates that possibly the infusion of synthetic CLA isomers was initiating the dry-off mechanisms in the mammary gland.

Table 2. **Effects of fat source and individual cow on milk casein content, coagulation parameters and pH**

Traits	Treatment[1]				SE	P-value
	SBM	RC	LC	GP		
Casein, %	2.92[ab]	2.78[a]	2.67[bc]	2.82[c]	0.05	0.0050
Milk pH	6.75	6.75	6.75	6.76	0.010	0.6639
RCT, min[2]	10.3[ab]	11.1[a]	10.7	11.1[b]	0.22	0.0440
E_{30}, mm[3]	24.8[ab]	21.3[a]	21.6[bc]	22.9[c]	0.93	0.0471
	Cow				SE	P-value
	20	28	226	231		
Casein, %	2.82[a]	2.54[ab]	3.04[ab]	2.80[b]	0.05	<0.0001
Milk pH	6.81[ab]	6.78[b]	6.65[ab]	6.77[a]	0.010	<0.0001
RCT, min[2]	11.2[a]	11.5[b]	8.5[ab]	12.0[a]	0.22	<0.0001
E_{30}, mm[3]	25.4[a]	20.9[a]	31.1[a]	13.3[a]	0.93	<0.0001

[a,b,c,d]- Means with different superscript letters within the same row are significantly different (P<0.05)
[1] – Fat source: SBM- soybean meal, RC- rapeseed cake, LC-linseed cake, GP-gold of pleasure cake
[2] – RCT – rennet coagulation time, min
[3] – E_{30} – curd firmness 30 min after rennet addition, mm

The dietary fat source had a significant effect (P<0.05) on milk coagulation time and curd firmness. Improvement of curd firmness by GP, as compared to RC and LC milk, could be mostly explained by the increase of casein content (Table 2). A higher correlative relationship was found between curd firmness and casein content in the milk (P<0.001) by Kreuzer et al. (1996). The response of milk casein content, milk renneting properties and pH by individual cows (P<0.0001) was greater than to a treatment effect (Table 2).

Fatty acid composition of cheese. Fatty acid composition of cheese followed the same trends as that of milk, suggesting that processing of CLA-enriched milk, received from cows that had received the GP diet into Edam type cheese did not alter the FA structure (Tables 1 and 3). Our results support the findings of other researchers who reported similar minor changes in FA composition of milk and cheese manufactured from that milk (Dhiman et al., 1999; Allred et al., 2006; Zhang et al., 2006).

The proportion of short- ($\Sigma C_4 – C_{10}$) and medium-chain ($\Sigma C_{12} – C_{16}$) FA, decreased in cheese from the LC, RC and GP diets compared to the control diet (Table 3). Lower *de novo* synthesis of short- and medium-chain FA in milk as well as their lower concentrations in cheese were probably due to an increased supply of long chain fatty acids from the experimental fat source. The decrease in medium-chain fatty acids ($\Sigma C_{12} – C_{16}$) may represent a marked improvement in the FA profile of cheese, because these FA, have been reported to constitute the hypercholesterolaemic portion of fat (Ney, 1991).

Special attention should be paid to the amount of CLA in GP (4.94%) cheese, which was 8.2 and 6.0 times higher than that of the control and RC groups (Table 3). Normally, CLA content in various types of cheeses varies from 0.34 to 1.07% of fat (Dhiman et al., 2005). The proportions of n3 and n6 FA were significantly higher in cheese from the GP treatment than from the control, RC and LC treatments (Table 3). Recent studies have shown a significant increase in n3/n6 FA only in milk from cows supplemented with fish oil (Baer et al., 2001; Allred et al., 2006).

Effect of type of supplemental fat on cheese quality parameters. The fat content in cheese dry matter did not differ between the diets, despite our assumptions. The conversion of milk fat from RC (4.15%) and SBM (3.95%) milk to cheese fat was ineffective (Tables 1 and 4). This suggests that there were higher losses of fat in whey during the manufacture of cheese. A significant change in cheese pH (P<0.05) was observed when fat a supplement was fed (Table 4).

Scores from the ten non-trained sensory panelists for cheese showed a slight treatment effect on the overall quality score, texture and colour (P<0.05). In cheese no flavour and taste differences among treatments were found (except between LC and GP), although the presence of specific flavour (above perceptible level) was much higher in the GP than in other treatments.

Table 3. **Cheese fatty acid composition, g/100 g total fatty acids**

	Treatment[1]				SE	P-value
	SBM	RC	LC	GP		
C4:0	4.98	4.73	4.65	4.09	0.324	0.1949
C6:0	2.47[a]	2.20[b]	2.27[c]	1.79[abc]	0.111	0.0125
C8:0	1.20[a]	1.04[a]	1.08[b]	0.85[ab]	0.048	0.0058
C10:0	2.55[ab]	2.06[a]	2.16[b]	1.70[ab]	0.114	0.0058
C12:0	2.81[abc]	2.24[a]	2.32[b]	2.00[c]	0.108	0.0051
C14:0	11.09[ab]	9.69[a]	9.68[b]	8.40[a]	0.400	0.0092
C14:1 t-9	0.002	nd	0.001	0.02	0.006	0.1694
C14:1 c-9	1.03	0.89	0.81	1.03	0.895	0.2433
C15:0	0.93[a]	0.84[ab]	0.86	0.93[b]	0.027	0.0595
C15:0 c-10	0.31[a]	0.27[b]	0.27[c]	0.22[abc]	0.015	0.0151
C16:0	34.44[abc]	22.40[a]	24.04[b]	19.55[c]	1.619	0.0017
C16:1 t-9	0.06[a]	0.07[b]	0.11[c]	0.51[abc]	0.077	0.0083
C16:1 c-9	1.38	1.04	0.99	1.39	0.166	0.1799
C17:0	0.44[ab]	0.38[a]	0.39[b]	0.42[a]	0.009	0.0066
C17:1 c-10	0.18	0.16	0.14	0.18	0.015	0.2527
C18:0	9.12[ab]	13.46[a]	13.75[b]	4.92[ab]	1.051	0.0022
C18:1 t-6…t-8	0.26[ab]	0.78[ac]	0.41[cd]	0.91[bd]	0.078	0.0021
C18:1 t-9	0.20[a]	0.44[b]	0.36[c]	0.95[abc]	0.130	0.0142
C18:1 t-10	0.27[a]	0.69	0.26	0.82[a]	0.182	0.0997
C18:1 t-11	1.01[a]	1.41[b]	2.31[c]	8.83[abc]	1.432	0.0127
C18:1 c-9	18.28[a]	26.24[ab]	22.57[c]	15.22[bc]	1.579	0.0060
C18:1 c-11	0.45[ab]	0.96[a]	0.73[b]	1.27[ab]	0.078	0.0011
C18:2 t-11, c-15	0.12[a]	0.12[b]	0.56[c]	2.34[abc]	0.287	0.0025
C18:2 c-9, c-12 n6	1.03	1.12	1.08	1.15	0.153	0.8930
C18:2 c-9, t-11 (CLA)	0.60[a]	0.83[b]	1.26[c]	4.94[abc]	0.674	0.0062
C18:2 t-10, c-12 (CLA)	nd	nd	nd	nd	-	-
C18:3 c-9, c-12, c-15 n3	0.35[a]	0.41[b]	0.94[ab]	0.62[ab]	0.038	0.0002
C19:0	0.05[ab]	0.05[c]	0.10[ac]	0.08[b]	0.015	0.1071
C20:0	0.16[a]	0.25	0.16	0,.9[a]	0.078	0.1376
C20:1 c-11	0.49[a]	0.59[b]	0.77[ab]	1.6[ab]	0.041	<0.0001
C20:5 n3	0.03[a]	0.05[b]	0.04[c]	0.9[abc]	0.007	<0.0001
Other	3.73[a]	4.60[b]	4.78[c]	12.3[abc]	0.675	0.0002
Σ $C_4 - C_{10}$	11.19[a]	10.03[b]	10.28[c]	8.3[abc]	0.518	0.0226
Σ $C_{12} - C_{16}$	52.03[ab]	37.43[b]	39.08[a]	34.6[a]	1.439	0.0004
Σ Saturated[2]	70.23[ab]	59.34[b]	61.58[a]	45.11[ab]	1.986	0.0005
Σ Unsaturated[3]	26.04[ab]	36.06[ac]	33.64[bd]	42.6[cd]	2.057	0.0043
Σ Monounsaturated[4]	23.91[abc]	33.52[a]	29.74[b]	33.2[c]	1.671	0.0107
Σ Polyunsaturated[5]	2.13[a]	2.53[b]	3.90[c]	9.4[abc]	1.030	0.0048
Σ CLA[6]	0.60[a]	0.83[b]	1.26[c]	4.94[abc]	0.674	0.0062

[a,b,c,d]- Means with different superscript letters within the same row are significantly different (P<0.05)

[1] – Fat source: SBM- soybean meal, RC- rapeseed cake, LC-linseed cake, GP-gold of pleasure cake

[2] – $C_{4:0}$, $C_{6:0}$, $C_{8:0}$, $C_{10:0}$, $C_{12:0}$, $C_{14:0}$, $C_{15:0}$, $C_{16:0}$, $C_{17:0}$, $C_{18:0}$, $C_{19:0}$, $C_{20:0}$

[3] – $C_{14:1\ t-9}$, $C_{14:1\ c-9}$, $C_{16:1\ t-9}$, $C_{16:1\ c-9}$, $C_{18:1\ t-6,7,8}$, $C_{18:1\ t-9}$, $C_{18:1\ t-10}$, $C_{18:1\ t-11}$, $C_{18:1\ c-9}$, $C_{18:1\ c-11}$, $C_{18:2\ t-10,\ c-12}$ (CLA), $C_{18:2\ t-11,\ c-15}$, $C_{18:2\ c-9,\ t-11}$ (CLA), $C_{18:2\ c-9,\ c-12\ n6}$, $C_{18:3\ c-9,\ c-12,\ c-15\ n-3}$, $C_{20:1}$, $C_{20:5\ n3}$ (EPA)

[4] – $C_{14:1\ t-9}$, $C_{14:1\ c-9}$, $C_{16:1\ t-9}$, $C_{16:1\ c-9}$, $C_{18:1\ t-6,7,8}$, $C_{18:1\ t-9}$, $C_{18:1\ t-10}$, $C_{18:1\ t-11}$, $C_{18:1\ c-9}$, $C_{18:1\ c-11}$, $C_{20:1\ c-11}$

[5] – $C_{18:2\ t-10,\ c-12}$ (CLA), $C_{18:2\ t-11,\ c-15}$, $C_{18:2\ c-9,\ t-11}$ (CLA), $C_{18:2\ c-9,\ c-12\ n6}$, $C_{18:3\ c-9,\ c-12,\ c-15\ n3}$, $C_{20:5\ n3}$ (EPA)

[6] – $C_{18:2\ c-9,\ t-11}$, $C_{18:2\ t-10,\ c-12}$.

There was a statistical difference in overall quality scores for the treatments with a tendency for decrease in the LC, SBM, RC and GP treatments (Table 4; Figure 1). The increase of unsaturated FA proportion in milk through feeding fat has often resulted in softer cheeses, yet it can also introduce other defects such as oxidized flavour (Kivelä and Hakkarainen, 1983; Jaros et al., 2001; Jones et al., 2005; Khanal et al., 2005). In the study by Ryhänen et al. (2005), cheese manufactured from CLA-enriched milk fat appeared to require a longer ripening period. Possibly the longer ripening time is required to attain satisfactory grading scores by cheese produced from cows fed GP diet. The data indicate that inclusion of fat supplement in the diet is a more important factor affecting cheese quality parameters than the individual cow factor (Table 4).

Table 4. **Effect of type of supplemental fat on cheese quality parameters**

Traits	Treatment[1]				SE	P-value
	SBM	RC	LC	GP		
Cheese dry matter, %	56.5	56.4	57.2	56.0	1.34	0.9017
Cheese pH	5.42[a]	5.52[b]	5.38	5.26[ab]	0.044	0.0147
Fat, %	29.9	29.7	30.8	30.1	1.14	0.8766
Fat in dry matter, %	52.5	51.3	54.3	53.7	1.41	0.3793
Overall quality score	3.98[a]	3.65[b]	4.26[bc]	3.49[ac]	0.17	0.0474
Texture and colour	4.19[a]	3.80	4.28[b]	3.63[ab]	0.16	0.0477
Taste and flavour	3.84	3.68	4.18[a]	3.03[a]	0.30	0.1002
Appearance	4.28	4.12	4.28	3.88	0.14	0.1636
Consistence	3.94	3.58[a]	4.17[a]	3.61	0.18	0.1224
	Cow				SE	P-value
	20	28	226	231		
Cheese dry matter, %	58.2[a]	57.6	56.4	53.9[a]	1.34	0.1096
Cheese pH	5.42	5.39	5.36	5.42	0.044	0.7163
Fat, %	31.0	32.3[ab]	28.5[a]	28.8[b]	1.14	0.0999
Fat in dry matter, %	53.1	56.1[ab]	50.5[a]	52.0[b]	1.41	0.0870
Overall quality score	4.22[ab]	3.63[a]	3.84	3.70[b]	0.17	0.0798
Texture and colour	4.36[ab]	3.77[a]	3.87	3.90[b]	0.16	0.0741
Taste and flavour	4.25[a]	3.27[a]	3.55	3.66	0.30	0.1274
Appearance	4.32	4.18	4.11	3.95	0.14	0.2537
Consistents	4.08[a]	3.82	3.92	3.47[a]	0.18	0.1194

[a,b,c,d]- Means with different superscript letters within the same row are significantly different ($P<0.05$)
[1] – Fat source: SBM- soybean meal, RC- rapeseed cake, LC-linseed cake, GP-gold of pleasure cake

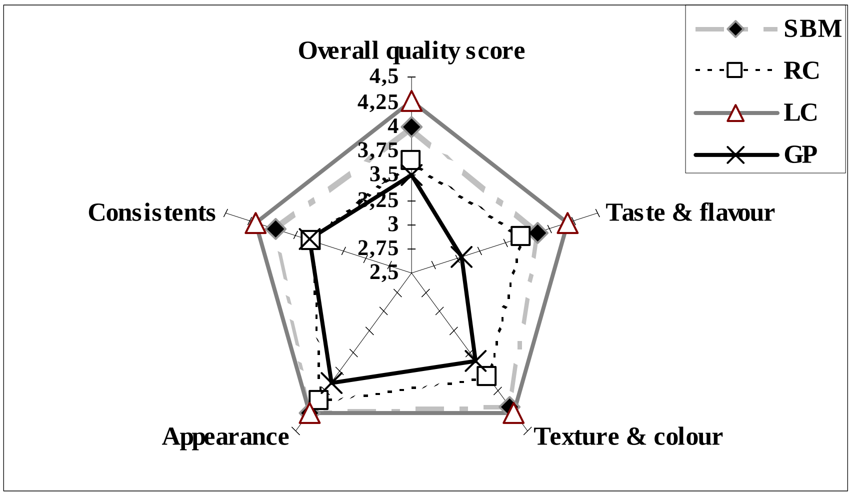

Figure 1. **Sensory attributes of control and experimental cheese**

Conclusions. The experimental results suggest that fat supplementation affects cheese fatty acids composition, milk coagulation parameters and cheese quality properties, depending on the degree of saturation the fat supplement. Feeding lactating dairy cows a diet high in linoleic acid (*Camelina sativa* diet) resulted in the greatest increases in the concentration of cheese CLA.

Acknowledgements. This research was funded by the Estonian Ministry of Agriculture and the Estonian Ministry of Education and Research (theme No B2595).

References

1. AbuGhazaleh, A.A., Schingoethe, D.J., Hippen, A.R., Whitlock, L.A. Feeding fish meal and extruded soybeans enhances the conjugated linoleic acid (CLA) content of milk. J. Dairy Sci. 2002. 85. P. 624-631.

2. Allred, S.L., Dhiman, T.R., Brennan, C.P., Khanal, R.C., McMahon D.J., Luchini, N.D. Milk and cheese from cows fed

calcium salts of palm and fish oil alone or in combination with soybean products. J. Dairy Sci. 2006. 89. P. 234-248.

3. Avramis, C.A., Wang, H., McBride, B.W., Wright, T.C., Hill, A.R. Physical and processing properties of milk, butter and cheddar cheese from cows fed supplemental fish meal. J. Dairy Sci. 2003. 86. P. 2568-2576.

4. Baer, R.J., Ryali, J., Schingoethe, D.J., Kasperson, K.M., Donovan, D.C., Hippen, A.R., Franklin, S.T. Composition and properties of milk and butter from cows fed fish oil. J. Dairy Sci. 2001. 84. P. 345–353.

5. Bell, J.A. and Kennelly, J.J. Short communication: Post-ruminal infusion of conjugated linoleic acids negatively impacts milk synthesis in Holstein cows. J. Dairy Sci. 2003. 86. P. 1321-1324.

6. Cant, J.P., DePeters, E.J., Baldwin, R.L. Mammary amino acid utilization in dairy cows fed fat and its relationship to milk protein depression. J. Dairy Sci. 1993. 76. P. 762-774.

7. Chouinard, P.Y., Corneau, L., Sæbø, A., Bauman, D.E. Milk yield and composition during abomasal infusion of conjugated linoleic acids in dairy cows. J. Dairy Sci. 1999. 82. P. 2737-2745.

8. Christie, W. W. A simple procedure for transmethylation of glycerolipids and cholesterol esters. – Journal of Lipid Research. 1982. 23. P. 1073-1075.

9. Coppock, C.E., Wilks, D.L. Supplemental fat in high-energy rations for lactating cows: effects on intake, digestion, milk yield and composition. J. Anim. Sci. 1991. 69. P. 3826-3837.

10. DePeters, E.J., Cant, J.P. Nutritional factors influencing the nitrogen composition of bovine milk: A review. J. Dairy Sci. 1992. 75. P. 2043-2070.

11. Dhiman, T.R., Helmink, E.D., McMahon, D.J., Fife, R.L., Pariza, M.W. Conjugated linoleic acid content of milk and cheese from cows fed extruded oilseeds. J. Dairy Sci. 1999. 82. P. 412-419.

12. Dhiman, T.R., Nam, S-E., Ure, A.L. Factors affecting conjugated linoleic acid content in milk and meat. Critical Reviews in Food Science and Nutrition. 2005. 45. P. 464-482.

13. Jaros, D., Ginzinger, E., Tschager, E., Leitgeb, R., Rohm, H. Application of oilseed feeding to reduce firmness of hard cheeses produced in the winter feeding period. International Dairy Journal. 2001. 11. P. 611-619.

14. Jones, E.L., Shingfield, K.J., Kohen, C., Jones, A.K., Lupoli, B., Grandison, A.S., Beever, D.E., Williams, C.M., Calder, P.C., and Yaqoob, P. Chemical, physical, and sensory properties of dairy products enriched with conjugated linoleic acid. J. Dairy Sci. 2005. 88. P. 2923-2937.

15. Khanal, R.C., Dhiman, T.R., Ure, A.L., Brennand, C.P., Boman, R.L., McMahon, D.J. Consumer acceptability of conjugated linoleic acid-enriched milk and cheddar cheese from cows grazing on pasture. J. Dairy Sci. 2005. 88. P. 1837-1847.

16. Kivelä, T., Hakkarainen, H. Fatty acid composition of milk in relation to the quality of cheese. Finnish journal of dairy science. 1983. 41. P. 35-41.

17. Kokassaar, U., Vihalemm, T., Zilmer, M. Õige toit. 1999. Tartu.

18. Kreuzer, M., Schulz, J.-P., Fry, C., Abel, H. Rennet coagulation properties of milk from cows at three stages of lactation supplied with graded levels of an antimicrobial feed supplement. Milchwissenschaft. 1996. 51(5). S. 243-247.

19. Kübarsepp, I.., Henno, M., Kärt, O., Tupasela, T. A comparison of the methods for determination of the rennet coagulation properties of milk. Acta Agriculturae Scandinavica, Section A – Animal Science. 2005. 55(4). P.145-148.

20. Madison-Anderson, R.J., Schingoethe, D.J., Brouk, M.J., Baer, R.J., Lentsch, M.R. Response of lactating cows to supplemental unsaturated fat and niacin. J. Dairy Sci. 1997. 80. P. 1329-1338.

21. Ney, D.M. Potential for enhancing the nutritional properties of milk fat. J. Dairy Science. 1991. 74. P. 4002-4012.

22. Roche, H.E., Noone, E., Nugent, A., Gibney, M.J. Conjugated linoleic acid: A novel therapeutic nutrient? Nutr. Res. Rev. 2001. 14. P. 173-187.

23. Rossell, J.B. Intermediate shelf life products as illustrated by fats and fatty foods. Food. Sci. Technol. Today. 1989. 3. P. 235-240.

24. Ryhänen, E.-L., Tallavaara, K., Griinari, J.M., Jaakkola, S., Mantere-Alhonen, S., Shingfield., K.J. Production of conjugated linoleic acid enriched milk and dairy products from cows receiving grass silage supplemented with a cereal-based concentrate containing rapeseed oil. International Dairy Journal. 2005. 15. P. 207-217.

25. SAS Institute. SAS/STAT 9.1 user's guide. Cary, NC, USA: SAS Institute Inc, 2004.

26. Zhang, R.H., Mustafa, A.F., Zhao, X. Effects of feeding oilseeds rich in linoleic and linolenic fatty acids to lactating ewes on cheese yield and on fatty acid composition of milk and cheese. Animal Feed Science and Technology. 2006. 127. P. 220-233.