Fatty acid content in milk of dairy cows on a diet with high fat content derived from rapeseed

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ABSTRACT: Two groups of dairy cows, Czech Red-pied × Ayrshire × Red Holstein crossbreds, received a diet with either production mixture with rapeseed, rapeseed cakes and rapeseed oil (Energol; E-group; final feed mixture with 62 g of crude fat per kg of dry matter, DM) or control production mixture (C-group; crude fat content in total feed mixture 37 g/kg DM). Milk samples were taken on the 14th, 30th, 60th and 90th day of lactation, and basic milk constituents and fatty acid content in milk fat were determined. E- and C-groups did not differ in either milk yield or yield of milk fat, milk protein and lactose ($P > 0.05$). Lactose, calcium, milk protein and casein content increased linearly ($P < 0.05$) with the increasing day of lactation both in E-milk and in C-milk. Casein content in E-milk was lower ($P < 0.05$) than in C-milk but total lipid content did not differ ($P > 0.05$) from that in C-milk. Dietary rapeseed decreased ($P < 0.05$) palmitic acid content in milk by 20 percentage units and at the same time increased ($P < 0.05$) oleic acid content by 10 percentage units in comparison with control milk; the ratio of total C16/total C18 fatty acids was consequently twice lower ($P < 0.01$) in E-milk. As far as polyunsaturated fatty acids (PUFA) are concerned, the contents of linoleic acid (LA), α-linolenic acid (LNA) and eicosapentaenoic + docosahexaenoic acid were higher ($P < 0.05$) in E-milk; however, the PUFAn-6/PUFAn-3 ratio was not different between E- and C-milk. It was concluded that 1 litre of E-milk could provide 20% of both LA and LNA daily requirement.

Keywords: nutritive value; oleic acid; polyunsaturated fatty acids

One of the serious objections to milk, which is otherwise considered an important component of human nutrition, is its rather unfavourable composition of fatty acids. Therefore there have been numerous attempts to manipulate the composition of milk fat. Apart from genetic approaches, the content of milk components can be influenced by dietary manipulation (Kennely and Glimm, 1998). The percentage of undesirable saturated fatty acids (SFA) can be decreased and the percentage of desirable monounsaturated (MUFA) and polyunsaturated (PUFA) fatty acids can be increased at the same time by inclusion of feed components to the diet such as rapeseed, soybean or linseed oils (Dhiman et al., 2000; Reklewska et al., 2002; Collomb et al., 2004) or rapeseed cake (Jahreis et al., 1996; Komprda et al., 2000; Komprda et al., 2001).

When supplementing components rich in plant oils to the diet for dairy cows, one must be aware of negative effects of large amounts of fat on the activity of rumen microflora with a consequent decrease in milk yield and milk fat content (Collomb et al., 2004).

On the other hand, several authors reported increased milk yield (albeit consequently decreased milk protein concentration) when they used higher fat supplementation to the diet for lactating cows

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(for a review see the paper of Wu and Huber, 1994). Such a type of diet could also possibly improve the *post partum* physiology of dairy cows (McNamara, 2004). One of the objectives of the present study was therefore to evaluate yield traits and changes in the composition of milk of dairy cows fed a diet with higher-than-usual fat content. The results regarding physiological parameters of dairy cows are presented elsewhere. However, because one of the feed mixtures in this experiment contained rapeseed oil, a possible effect of high oleic acid content in this component on an improvement of the nutritive value of milk (changes in the content of physiologically important fatty acids) was evaluated, which was the main objective of the present experiment.

Table 1. Composition of feed mixtures

Component	Daily ration (kg of fresh matter per dairy cow and day)	
	E[1]	C[2]
Clover silage	16.00	16.00
Maize silage	15.00	15.00
Meadow hay	2.00	2.00
Production mixture[3]	5.00	5.00
Energol[4]	0.30	/
Vitamin/mineral supplement[5]	0.45	0.42

[1]experimental feed mixture with rapeseed; [2]control feed mixture; [3]the composition see Table 3; [4]distillate of rapeseed oil fatty acids and their salts; [5]total contents of the minerals and vitamins in feed mixtures see Table 3

MATERIAL AND METHODS

Animals, diets and sample taking

The experiment was carried out on the dairy cooperative farm Žichlínek, Czech Republic, in the months of April – December 2002. Twenty-eight dairy cows with average live weight 600 kg, Czech Red-pied × Ayrshire × Red Holstein crossbreds, were randomly picked out in the herd with average production 6 000 l milk per lactation. Selected dairy cows were divided into two groups based on the rule of similar pairs, kept individually and fed a diet calculated to ensure the production of 30 l per day.

Feed mixtures were based on clover silage, maize silage and meadow hay (composition and nutrient

Table 2. Nutrient and energy content of feed mixtures

Component	Amount in 1 kg of dry matter		Component	Amount in 1 kg of dry matter	
	E[1]	C[2]		E[1]	C[2]
Dry matter (%)	51.2	51.3	Chlorine (g)	4.1	3.9
Crude protein (g)	170	170	Magnesium (g)	2.7	2.5
Crude fat (g)	62	37	Sulphur (g)	1.4	1.4
Crude fibre (g)	156	144	Copper (mg)	21	21
Starch (g)	63	115	Manganese (mg)	118	112
PDIA[3] (g)	43	43	Zinc (mg)	116	110
PDIN[4] (g)	107	109	Selenium (mg)	0.4	0.4
PDIE[5] (g)	86	90	Iodine (mg)	2.3	2.2
NEL[6] (MJ)	6.72	6.65	Vitamin A (mg)	3.1	2.9
Calcium (g)	12.9	8.2	Vitamin D (mg)	0.04	0.04
Phosphorus (g)	6.1	5.8	α-tocopherol (mg)	45	43
Sodium (g)	2.0	1.9	Niacin (mg)	25	17
Potassium (g)	16.8	17.2			

[1]experimental feed mixture with rapeseed; [2]control feed mixture; [3]feed protein undegraded in the rumen, digestible in the intestine; [4]microbial protein synthesized in the rumen from degraded dietary nitrogen when energy and other nutrients were not limiting; [5]microbial protein synthesized in the rumen from available energy when degradable nitrogen and other nutrients were not limiting; [6]net energy of lactation

and energy content see Table 1 and 2, respectively) and differed in the composition of the production mixture (Table 3). The experimental feed mixture contained an extra component, an energetic feed based on the distillate of rapeseed oil fatty acids and their calcium salts called Energol (produced by a patented technology, subject to a trade secret of the cooperative Žichlínek, Czech Republic). The composition of feed mixtures from the aspect of the quantitatively most important fatty acids is presented in Table 4.

Milk samples were taken when particular dairy cows from either group reached the 14th, 30th, 60th and 90th day of lactation, respectively. An average milk sample from each dairy cow was taken during milking at the amount of 1 l. Samples were cooled to the temperature 4°C and transported immediately to the laboratory. The content of basic milk constituents (including fat) was determined within 24 hours on receipt in the laboratory. Extracted milk fat was stored at –20°C in dark wide-neck bottles until fatty acid analyses.

Determination of milk fat and fatty acid (FA) content

Milk (500 ml) was centrifuged at 2 500 rpm. Milk fat was consecutively extracted seven hours with diethyl ether under the reflux and determined gravimetrically. An internal standard (2.5 mg C15:0/ml hexane) was added to the 70–80 mg aliquot of extracted milk fat and the aliquot was saponified 30 minutes in the water bath at 60–70°C with 6 ml of the methanolic solution of KOH (1 mol/l). The saponifiable part was reesterified by heating for further fifteen minutes after the addition of 10 ml of methanol (saturated with 14% HCl). Fatty acid methyl esters (FAMEs) were extracted in a separation funnel with H_2O/hexane mixture. The extract

Table 3. Composition of production mixtures

Experimental production mixture		Control production mixture	
Component	Amount (g in 5 kg of fresh matter)	Component	Amount (g in 5 kg of fresh matter)
Glycerol	400	Soybean meal	1 250
Rapeseed cakes	2 300	Maize (seeds)	675
Oats (seeds)	500	Wheat (seeds)	1 000
Rapeseed (seeds)	850	Oats (seeds)	250
Whey	350	Wheat bran	500
Molasses	250	Flax (seeds)	250
Ground limestone	350	Propylene glycol	375
		Whey	350
		Molasses	250
		Ground limestone	100

Table 4. Percentage of the quantitatively most important fatty acids in feed mixtures and intake of these fatty acids

Fatty acid	Percentage in feed mixture (% of total determined fatty acids)		Intake estimation[1] (g/day)	
	E[2]	C[3]	E[2]	C[3]
C16:0	7.5	11.0	110	166
C18:1	51.9	36.9	763	558
C18:2n-6	24.4	28.3	357	429
C18:3n-3	11.0	16.9	161	255

[1]refusals were not weighed and analysed, only estimated; [2]experimental feed mixture with rapeseed; [3]control feed mixture

was dried by the addition of anhydrous Na_2SO_4 and evaporated on a rotary vacuum evaporator at 60°C. The residue was dissolved in 1 ml of hexane and injected (2 µl) onto the chromatographic column. FAMEs were separated using a gas chromatograph HP 4890 (Hewlett-Packard) with capillary column Omegawax TM250 30 m × 0.25 mm × 0.25 µm. The temperature range was from 60°C to 240°C with the temperature increase 30°C/min. Injector and detector temperature was 280°C and 300°C, respectively. FAMEs were detected with the flame ionization detector and identified according to the retention times using external standards from C4:0 to C22:6 (Sigma).

The content of the individual *FA* was expressed by the equation:

$$W_{FA} = (M_{IS} \times A_{FA}/A_{IS})/M_{TL} \times K \times 1\,000 \text{ g/kg}$$

where: W_{FA} = the mass fraction of the given *FA* in a milk fat sample, in g/kg

M_{IS} = the mass of the internal standard added to the test portion of fat sample, in g

A_{FA} = the area under the peak corresponding to the given *FA*

A_{IS} = the area under the peak of the internal standard in the test portion

M_{TL} = the mass of the test portion of milk fat sample, in g

K = the relative calibration factor of the given *FA*

K was calculated as follows:

$$K = (M_{ES}/A_{ES})/k$$

where: M_{ES} = the mass of the given *FA* in the external standard, in mass units

A_{ES} = the peak area of the given *FA* in the external standard, in area units

K = the calibration factor of the internal standard fatty acid, in mass units per area unit

FA content was calculated in mg 100/g of milk fat and then expressed both in % of total determined *FA* and in mg/L of milk, using the measured values of fat content in milk and milk density.

Determination of other parameters of milk composition

The following parameters were determined: solids (gravimetrically; ČSN 570530, 1973), total protein, casein and whey proteins (spectrophotometrically, using the Pro-Milk apparatus, Foss Elektric, Denmark), lactose (polarimetrically; Czech State Standard 570530, 1973), calcium (by the complexometric titration using fluorexon indication; Czech State Standard 570530, 1973).

In addition, somatic cell count was measured on Fossomatic apparatus (Foss Elektric).

Statistical evaluation

The effect of rapeseed inclusion in the diet was evaluated by one-way classification of the variance ratio test, including Duncan's test. Dependence of selected parameters on the stage of lactation was calculated using regression analysis (significance of the linear and quadratic term was tested). Statistical package Unistat, version 4.53 (Unistat Ltd., London, England, 1984–1999) was used for the above calculations as well as for the calculation of basic statistical characteristics.

RESULTS AND DISCUSSION

Hygienic status of milk

The mean of somatic cells counts (SCC) for the whole lactation period (n = 47 and 51 for experimental and control dairy cows, respectively) of milk from dairy cows fed the diet with rapeseed (71×10^3/ml) was significantly lower ($P < 0.05$) in comparison with milk from the control group (284×10^3/ml). SCC did not change in the course of lactation in either group ($P > 0.05$).

Nutrient content in milk and yield of milk and basic milk constituents

Milk yield and yield of milk fat, total milk protein and lactose are presented in Table 5. No differences in any of these traits were found between the experimental and control group of dairy cows ($P > 0.05$). As regards yield of milk and milk constituents in dairy cows fed the diet based on rapeseed as compared to various control diets, the results of the present experiment are in agreement with the data of Šimek et al. (2000), Tymchuk et al. (1998) or Komprda et al. (2001). However, Komprda et al. (2000) reported a lower yield of milk fat in dairy cows receiving the diet based on rapeseed cakes in comparison with soybean meal; on the other hand,

Table 5. Yield of milk and basic milk constituents (mean ± standard error of the mean)

kg/day	Feed mixture	
	E[1] (n = 47)	C[2] (n = 51)
Milk	26.9 ± 1.13	26.8 ± 0.92
Milk fat	1.03 ± 0.03	0.96 ± 0.03
Milk protein	0.89 ± 0.02	0.84 ± 0.03
Lactose	1.34 ± 0.03	1.32 ± 0.03

[1]experimental feed mixture with rapeseed; [2]control feed mixture
$P > 0.05$

DePeters et al. (2001) found significantly higher milk yield in dairy cows fed the diet with canola in comparison with control.

Significant changes in the nutrient content of the Energol-milk (Y; in g/100 g milk, in the case of calcium in g/kg milk) with the increasing stage of lactation (X, days) were observed in the present experiment in the case of lactose ($Y = 5.4 - 0.003X$, $R^2 = 0.21$, $P = 0.001$), calcium ($Y = 1.23 - 0.002X$, $R^2 = 0.07$, $P = 0.045$), milk protein ($Y = 3.36 - 0.003X$, $R^2 = 0.08$, $P = 0.046$) and casein ($Y = 2.65 - 0.002X$, $R^2 = 0.09$, $P = 0.033$). The relationships regarding control milk (not presented here) were similar. These findings are contrary to the results of Komprda et al. (2001), who found no differences between the samples of milk from 21st, 42nd and 100th day of lactation in the content of lactose, calcium, total milk protein and casein in milk of dairy cows fed the diet with heat-treated rapeseed cakes.

The means over the whole lactation period of the lactose content did not differ ($P > 0.05$) between Energol milk and control milk (5.09 and 5.11 g per 100 g) in the present experiment. The same was true in the case of calcium (1.15 and 1.18 g/kg), total solids (12.0 and 12.2 g/100 g), crude protein (3.23 and 3.35 g/100 g) and whey protein (0.70 and 0.72 g/100 g, respectively). In this point (with the exception of lactose), the present results are in agreement with our previous findings regarding the comparison of milk produced with the feed mixture with rapeseed cakes and the control feed mixture (with soybean meal; Komprda et al., 2001). However, casein content in Energol milk (2.53 mg per 100 g) was significantly lower ($P < 0.05$) in comparison with control milk (2.66 mg/100 g) in the present experiment. Similar results were obtained by Komprda et al. (2000), who compared milk of dairy cows fed the diet with rapeseed cakes and control diet with soybean meal. The quoted authors explained the findings by a lower protein content in the experimental diet (as a confirmation of the data of Kennely and Glimm, 1998), which, however, was not the case in the present experiment. In the present experiment, a possible explanation could be a high crude fat content in the experimental feed mixture (6.2%; Table 2) that could suppress microbial protein synthesis in the rumen with the consequence of lower (insignificantly, $P > 0.05$) total protein content and significantly lower casein (and also significantly lower, $P < 0.05$, urea nitrogen) in the Energol milk.

Milk fat content did not change ($P > 0.05$) in the course of lactation period either in the Energol group or in the control group in the present experiment. Moreover, Energol milk and control milk did not differ in fat content ($P > 0.05$) in any of the four recorded stages of lactation period. The mean fat content over the whole lactation period was 3.6 and 3.2 g/100 g milk in Energol and control group, respectively. Loor et al. (2002) and DePeters et al. (2001) found fat content in experimental and control milk of Holstein dairy cows 3.3 and 3.6%, and 3.5% and 3.7%, respectively, in similar experiments with rapeseed (canola) oil and higher fat content in the diet.

Milk fat content is influenced among other things by dietary fibre (Kennely and Glimm, 1998) and by dietary fat (Jahreis et al., 1995). More acetate is produced in the rumen at the expense of propionate with consequent increase of milk fat concentration when the content of dietary fibre is higher. On the other hand, growth restriction of rumen microorganisms and therefore the restriction of acetate production follow from a higher concentration of dietary fat (Jahreis et al., 1996). These two trends might act contradictory as far as the feed mixture with rapeseed in the present experiment is concerned; it is apparent from Table 2 that the experimental feed mixture had somewhat higher crude fibre content and nearly twice as high content of crude fat than the control feed mixture.

Fatty acid content in milk

Despite of only marginal differences in fat content, fat fractions important from the aspect of human nutrition differed significantly in milk from dairy cows fed the diet with rapeseed as compared to

the control. Regarding fatty acids which are quantitatively most important in milk, rapeseed in the diet significantly ($P < 0.05$) decreased the palmitic acid (C16:0) percentage in all recorded stages of lactation, on average by 20% (Table 6), as a consequence of the substantially lower percentage of this fatty acid in the experimental feed mixture (Table 4). Similarly, DePeters et al. (2001) reported a decrease in the palmitic acid percentage in milk fat of dairy cows fed the diet with canola oil by more than 7 percentage units in comparison with control.

On the other hand, the percentage of nutritionally favourable monounsaturated oleic acid (C18:1; OA) increased ($P < 0.05$) in milk produced using Energol in the diet in comparison with control milk by more than 10 percentage units in each of the recorded stages of lactation (Table 6). These figures correspond with the data of DePeters et al. (2001; increase in OA from 15 to 21 g/100 g of milk fat of dairy cows fed the diet with canola oil) or of Loor et al. (2002; increase in OA in a similar experiment with canola oil from 16% to 26%), and data of Givens et al. (2003), who found an increase in OA content from 18.1% (control) to 40% of the sum of total determined fatty acids in milk of dairy cows fed the diet with whole cracked rapeseed. Rapeseed oil content in the cow's daily ration was nearly 2 kg in the experiment of Givens et al. (2003); however, it was only a half of this amount in the present experiment (0.3 kg from Energol and 0.65 kg from 5 kg of the experimental production mixture).

Contents of saturated (SFA) and monounsaturated (MUFA) fatty acids in experimental and control milk, expressed in grams in one litre of milk, are presented in Figure 1. SFA content in milk from dairy cows fed the diet with rapeseed oil (Energol) or the control diet did not differ ($P > 0.05$) due to the fact that experimental milk had a lower ($P < 0.05$) content of palmitic acid, but a higher ($P < 0.05$) content of stearic acid (C18:0). Stearic acid, despite of its saturated nature, is as effective as C18:1 in reducing plasma cholesterol in man according to Kennely and Glimm (1998). Because of the substantially higher percentage of OA in the experimental diet (by nearly 30%; Table 4), oleic acid and consequently MUFA content in Energol milk

Table 6. The quantitatively most important fatty acids and ratios of the main groups of fatty acids in milk of dairy cows fed either the diet with rapeseed oil or the control diet during lactation

Trait	Time *post partum* (days)							
	14		30		60		90	
	E[1] (n = 10)	C[2] (n = 10)	E[1] (n = 14)	C[2] (n = 13)	E[1] (n = 10)	C[2] (n = 14)	E[1] (n = 13)	C[2] (n = 14)
Total lipid (%)	3.28^{ab}	3.22^{ab}	3.37^{ab}	2.65^{a}	3.76^{ab}	3.29^{ab}	4.12^{b}	3.32^{ab}
C16:0[3)]	24.3^{a}	30.8^{b}	24.2^{a}	32.2^{b}	23.0^{a}	34.5^{b}	23.8^{a}	37.0^{b}
C18:1[3)]	38.9^{b}	28.7^{a}	38.9^{b}	28.4^{a}	38.6^{b}	26.4^{a}	38.4^{b}	24.4^{a}
C16/C18	0.44^{a}	0.71^{b}	0.46^{a}	0.78^{b}	0.42^{a}	0.93^{b}	0.43^{a}	1.09^{b}
Σ SFA[3)4)]	53.5^{a}	64.4^{b}	53.5^{a}	64.9^{b}	53.7^{a}	67.0^{b}	54.1^{a}	68.4^{b}
Σ MUFA[3)5)]	41.5^{b}	31.1^{a}	41.2^{b}	31.2^{a}	40.7^{b}	31.2^{a}	40.6^{b}	27.7^{a}
Σ PUFA[3)6)]	5.0^{a}	4.5^{a}	5.2^{b}	3.9^{a}	5.5^{b}	3.9^{a}	5.3^{b}	3.9^{a}
PUFAn-6	4.1^{a}	3.6^{a}	4.2^{b}	3.1^{a}	4.5^{b}	3.2^{a}	4.2^{b}	3.2^{a}
PUFAn-3	0.9^{b}	0.9^{b}	1.0^{b}	0.7^{a}	1.0^{b}	0.7^{a}	1.0^{b}	0.7^{a}
SFA/MUFA	1.3^{a}	2.1^{b}	1.4^{a}	2.1^{b}	1.3^{a}	2.5^{b}	1.4^{a}	2.5^{b}
SFA/PUFA	11.0^{a}	14.5^{b}	10.8^{a}	16.9^{b}	9.9^{a}	18.1^{b}	10.6^{a}	18.6^{b}
SFA/UFA[7)]	1.2^{a}	1.9^{b}	1.2^{a}	1.9^{b}	1.2^{a}	2.2^{b}	1.2^{a}	2.2^{b}
MUFA/PUFA	8.6^{a}	7.0^{a}	8.0^{a}	8.1^{a}	7.4^{a}	7.6^{a}	7.9^{a}	7.3^{a}
PUFAn-6/PUFAn-3	4.5^{a}	4.1^{a}	4.2^{a}	4.2^{a}	4.6^{a}	4.3^{a}	4.3^{a}	4.5^{a}

[1]experimental feed mixture with rapeseed; [2]control feed mixture; [3]% of total determined fatty acids; [4]saturated fatty acids; [5]monounsaturated fatty acids; [6]polyunsaturated fatty acids; [7]unsaturated fatty acids (= MUFA + PUFA)

[a,b]means with different superscripts in lines differ significantly (Duncan's test; $P < 0.05$)

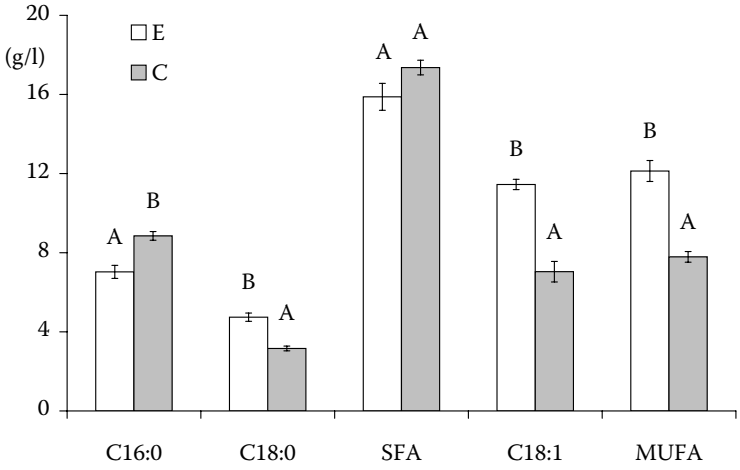

Figure 1. Contents of the quantitatively most important saturated (SFA) and monounsaturated (MUFA) fatty acids in milk of dairy cows fed the experimental diet with rapeseed + rapeseed cakes + rapeseed oil (E) or the control diet (C)

was higher ($P < 0.05$) in comparison with control milk (Figure 1). In a similar experiment Collomb et al. (2004) found 16.6 g of OA in 100 g of milk fat from dairy cows fed the diet with rapeseed in comparison with 11.3 g per 100 g of milk fat of the control. Our corresponding data recalculated to the same units are 30.9 and 21.1 g/100 g. Despite of the supposed extensive biohydrogenation of dietary OA in the rumen, it is possible to explain the larger difference between the above values within the present experiment by higher OA intake in the experimental feed mixture (more than 700 g per day; Table 4) in comparison with the experimental diet of Collomb et al. (2004) (258 g/day).

A possible transfer of polyunsaturated fatty acids (PUFA) from diet to milk is more complicated as compared to SFA or MUFA, as it is illustrated in the present experiment by a comparison of Table 4 and Figure 2. The percentage of linoleic acid (C18:2n-6, LA) and especially of α-linolenic acid (C18:3n-3, LNA) was higher in the control feed mixture (Table 4), an estimated intake of LNA was higher by 37% in the control group of dairy cows (due to the presence of flax seed in the control production mixture; Table 3). However, the content of LA, LNA, the sum of eicosapentaenoic (EPA) + docosahexaenoic acid (DHA) and the sum of PUFA were significantly higher in milk of dairy cows fed the diet with rapeseed (Figure 2). Both C18:2 and C18:3 are extensively biodehydrogenated in the rumen (Palmquist et al., 1993). It is possible to surmise that the total extent of rumen biodehydrogenation of E-diet PUFAs was lower in the present experiment due to very high fat content (despite of lower PUFA content) in this feed mixture (Table 2). Consequently, a higher percentage of PUFAs was transferred to E-milk in comparison with the control one. Another possible explanation ensues from the data of Loor et al. (2002): after a higher supply of C18:1 into the rumen extensive biohydrogenation of this fatty acid follows which has a sparing effect on the dietary LA and LNA; this was the case of the diet with rapeseed in the present experiment. Our data regarding LA (Figure 3) re-

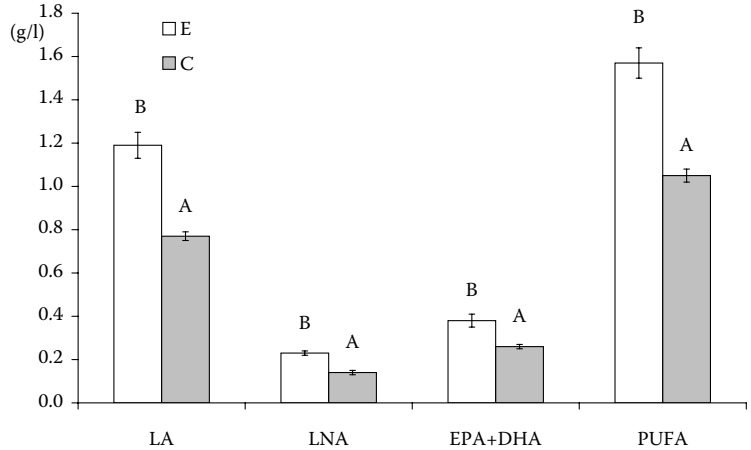

Figure 2. Contents of physiologically important polyunsaturated fatty acids in milk of dairy cows fed the experimental diet with rapeseed + rapeseed cakes + rapeseed oil (E) or the control diet (C); LA – linoleic acid; LNA – α-linolenic acid; EPA – eicosapentaenoic acid; DHA – docosahexaenoic acid

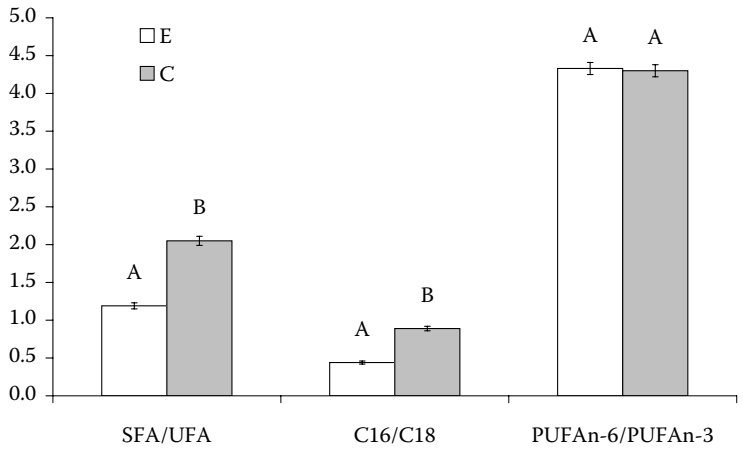

Figure 3. Fatty acid ratios, important from the aspect of human nutrition, in milk of dairy cows fed the experimental diet with rapeseed + rapeseed cakes + rapeseed oil (E) or the control diet (C); SFA – saturated fatty acids; UFA – unsaturated (= monounsaturated + polyunsaturated) fatty acids; C16 – sum of C16 fatty acids; C18 – sum of C18 fatty acids; PUFA – polyunsaturated fatty acids

calculated to milk fat (3.4 and 2.3 g/100 g of Energol and control milk fat, respectively) differ from the results of Collomb et al. (2004), who found a substantially lower content of C18:2 in milk fat from dairy cows fed the diet supplemented with rapeseed (1.6 g/100 g). This difference could be related to the higher intake of LA from the rapeseed (E) diet in the present experiment (Table 4) in comparison with the experiment of Collomb et al. (2004) (85 g LA per dairy cow and day). DePeters et al. (2001) reported no significant differences in LA content between milk of dairy cows fed the diet with canola oil or a control diet.

Although milk is considered a relatively poor source of essential PUFAs (Kennely and Glimm, 1998), one litre of Energol milk could provide 20% of the daily requirement of both LA and LNA according to the current state of knowledge regarding LA and LNA requirement (6 and 1 g per day, respectively; Cunnane, 2003).

Very important markers of healthy human nutrition, especially from the aspect of prevention of cardiovascular diseases, are ratios of main groups of fatty acids. Based on the FAO/WHO (1998) recommendation, the optimal ratio of the SFA : MUFA : PUFA intake as a percentage of total energy intake should be 1.3 : 2 : 1 in man. Milk from dairy cows fed the diet with rapeseed in the present experiment corresponded to the above optimum substantially better (9.1 : 7.3 : 1) than the control milk (18.4 : 8.6 : 1). SFA/UFA (unsaturated fatty acids, UFA = MUFA + PUFA) ratio of the Energol milk was on average by more than 70% lower in comparison with the control milk (Figure 3).

Because, as mentioned above, the intake of stearic acid is considered favourable (Kennely and Glimm, 1998), the ratio of total C16 fatty acids/total C18 fatty acids should be as low as possible in human nutrition. This ratio in cow's milk was significantly ($P < 0.05$) decreased by an inclusion of rapeseed into the diet in the present experiment (Figure 3).

The difference in PUFAn-6/PUFAn-3 ratio between experimental and control milk was not found in the present experiment ($P > 0.05$; Figure 3). According to Okuyama et al. (1997) this ratio should be as close to one as possible, the values lower than 5 are still acceptable. From this aspect, both Energol milk and control milk could be considered favourable food.

CONCLUSIONS

It follows from the results of the present experiment that the relatively high fat content in the feed mixture containing rapeseed, rapeseed cakes and rapeseed oil did not influence negatively either yield traits (milk yield, yield of milk fat, milk protein and lactose) or the content of basic milk constituents, including total solids (total lipid, total protein, lactose and calcium). The only exception was a lower content of casein in Energol milk.

The nutritive value of milk was positively influenced by inclusion of rapeseed in the feed mixture: the content of palmitic acid was substantially decreased and at the same time the contents of stearic acid, oleic acid, linoleic acid, α-linolenic acid and the sum of eicosapentaenoic + docosahexaenoic acid were significantly increased in milk of dairy cows fed the diet with rapeseed. It was concluded that Energol milk could provide 20% of the daily requirement of both essential fatty acids, LA and LNA.

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