Changes in fatty acid profile and iodine content in milk as influenced by the inclusion of extruded rapeseed cake in the diet of dairy cows

A. Veselý[1], L. Křížová[1], J. Třináctý[1], S. Hadrová[2], M. Navrátilová[3], I. Herzig[3], M. Fišera[4]

[1]Agriresearch Rapotín, Ltd., Rapotín, Czech Republic
[2]Research Institute for Cattle Breeding, Ltd., Rapotín, Czech Republic
[3]Veterinary Research Institute, Brno, Czech Republic
[4]Thomas Bata University, Zlín, Czech Republic

ABSTRACT: The aim of the study was to evaluate the effect of extruded rapeseed cake in diets of dairy cows on changes in milk fatty acid profile and iodine content in milk and on the thyroid gland status. An experiment was carried out on four lactating Holstein cows divided into 2 groups – experimental (R) fed a diet based on extruded rapeseed cake and control (S) fed a diet based on extruded full-fat soya. The experiment was divided into 4 periods of 42 days (21 days of preliminary period and 21 days of experimental period). Samples of milk and blood were taken three times a week during the experimental period. DMI was not affected by the treatment ($P > 0.05$). Milk yield and 4% FCM were lower in R compared to S ($P < 0.05$). Percentages of milk fat and protein were higher in R than in S ($P < 0.05$). The total content of SFA and UFA was not affected by the treatment ($P > 0.05$). However, the content of MUFA in R was higher (34.71 g/100 g) and the content of PUFA was lower (4.00 g/100 g) than in S (32.14 and 5.54 g/100 g, respectively ($P < 0.05$). The contents of C18:2 and C18:3 isomers and metabolites in R were lower than in S ($P < 0.05$). The content of *cis*-9, *trans*-11 CLA and *trans*-10, *cis*-12 CLA was lower in R (0.71 and 0.016 g/100 g) compared to S (0.97 and 0.022 g/100 g, respectively, $P < 0.05$). The index of atherogenicity and peroxidisability in R was lower than in S ($P < 0.05$). The index of desaturation was not affected by the treatment ($P > 0.05$). The mean daily intake of glucosinolates (Gls) in R was 50.14 mmol and resulted in a significant decrease in iodine concentration in milk in R (196.7 μg/l) in comparison with S (367.0 μg/l, $P < 0.05$) resulting in the lower daily iodine output in milk in R compared to S (4.4 and 9.2 mg/day, respectively, $P < 0.05$). Concentrations of T_3 and T_4 in blood plasma were not affected by the treatment ($P > 0.05$).

Keywords: extruded rapeseed cake; fatty acids; iodine; thyroid hormones; milk; dairy cows

Rapeseed is considered to be an adequate substitution of soya in dairy cow nutrition in some European countries because rapeseed cake is cheaper than soya or cereal concentrates, and feeding costs are lower (Amman, 1996). Thus, rapeseed products with various fat content have become a common component of dairy cow diets (Jahreis et al., 1996).

According to Lock and Shingfield (2004) milk fat typically contains a high proportion of saturated

Supported by the Ministry of Education, Youth and Sports of Czech Republic (Project No. MSM 2678846201) and the Ministry of Agriculture of the Czech Republic (Project No. 1G46086).

fatty acids (SFA, 70–75%), largely as a consequence of microbial biohydrogenation in the rumen, monounsaturated fatty acids (MUFA; 20–25%) and small amounts of polyunsaturated fatty acids (PUFA; 5%). An increased ratio of SFA (particularly C 12:0, C14:0, and C16:0) to unsaturated fatty acids (UFA) is associated with an increased risk of cardiovascular diseases and increased concentrations of total and low-density lipoprotein (LDL) cholesterol (e.g. Ulbricht and Southgate, 1991). Thus, there is a great deal of interest in the manipulation of the fatty acid (FA) profile of milk fat by lowering the SFA concentration and increasing the UFA concentration. Since genetics has a minor importance in influencing the milk FA composition, cow nutrition has been considered to be the primary factor influencing the milk FA profile (Jensen, 2002). The inclusion of rapeseed products to a diet of dairy cows changes the milk fatty acid profile because lipids of rapeseed are highly unsaturated, with oleic and linoleic acids as the principal components (Chouinard et al., 1997; McNamee et al., 2002). According to Focant et al. (1994) extruded rapeseeds in the diet increased the concentration of long-chain FA (mainly C18:0, C18:1, and C18:2) in milk and decreased the concentration of palmitic acid (C16:0).

In spite of its high CP content, well-balanced amino acid composition (Homolka et al., 2007) and favourable profile of FA, the use of rapeseed products in animal feeding is limited because of the glucosinolates (Gls) content. Gls, a large group of sulphur-containing secondary plant metabolites, are known to reduce the intake (Hill, 1991), induce hypertrophy of liver, kidney and thyroid (e.g. Burel et al., 2000; Tripathi et al., 2001) and induce also iodine deficiency (Burel et al., 2000). Iodine is necessary for the synthesis of the thyroid hormones thyroxine (T4) and triiodothyronine (T3), which regulate energy metabolism, and for the normal activity of thyroid hormones (Dahl et al., 2003). The amount of iodine incorporated into thyroid hormones in high-yielding cows may reach 4 to 4.5 mg iodine/day (Sorensen, 1962). About 80 to 90 % of dietary iodine is absorbed and most of the iodine not taken up by the thyroid gland is excreted in urine and milk (Miller et al., 1988) that normally contains from 30 to 300 μg iodine/l. The iodine content of milk generally increases as dietary iodine increases making the iodine content of milk a reasonable indicator of the iodine status (Berg et al., 1988). According to Laarveld et al. (1981b) feeding low-Gls diets resulting in the daily intake of 14 to 47 mmol Gls did not change milk iodine content while feeding low-Gls rapeseed meal at higher levels in dairy cows (intake of 37–63 mmol Gls/day) reduced milk iodine content. Thus, the Gls content of rapeseed products is an important factor that should be taken into account when using rapeseed products in ruminant diets.

The aim of the present study was to evaluate the effect of extruded rapeseed cake in diets of dairy cows on changes in the milk fatty acid profile and iodine content in milk and on the thyroid gland status in dairy cows.

MATERIAL AND METHODS

Animals and diets

An experiment was carried out on four high-yielding lactating Holstein cows (lactation 3–4, 16^{th}–46^{th} week of lactation). Cows were paired according to milk yield (27.3 kg, SEM = 1.7), divided into two groups and assigned to the replicated Latin square in double reversal design (Tempelman et

Table 1. Composition of diets (in g/kg of DM)

Ingredient	R[1]	S[1]
Maize silage (g/kg)	465	484
Meadow hay (g/kg)	79	82
Feed mixtures (g/kg)	456	434
Composition of supplemental mixture		
Sugar beet chippings (g/kg)	145	153
Barley (g/kg)	266	294
Oats (g/kg)	270	298
Rapeseed oil (g/kg)	12	–
Extruded rapeseed cake (g/kg)	258	–
Protex (extruded full-fat soya) (g/kg)	–	206
Premix (sum)[2] (g/kg)	51	51

[1]R = diet based on extruded rapeseed cake; S = diet based on extruded full-fat soya

[2]the premix contains (g/kg in supplemental mixture): sodium chloride 6; dicalcium phosphate 17; limestone 16; sodium bicarbonate 1; monosodium phosphate 2; magnesium phosphate 2; microelements and vitamin mixture 6

al., 2004). The experiment was divided into 4 periods of 42 days. Each period consisted of a preliminary period (21 days) and an experimental period (21 days). The experimental group of animals was fed a diet based on extruded rapeseed cake (R), the control group of animal was fed a diet based on extruded full-fat soya (S), i.e. in the first period 2 cows received R diet and the remaining 2 cows were fed S diet. In the subsequent period the cows were switched to the other treatment. Cows were fed individually twice daily (7.00 and 16.35 h) *ad libitum* the diet based on maize silage, meadow hay and supplemental mixture (Table 1).

Sampling and analyses

In feed and feed refusals (samples were taken twice a week in the experimental periods) the following parameters were estimated according to AOAC (1984): crude protein (CP, No. 7021), ash (No. 7009) and fat (No. 7060). DM was determined after drying at 55°C, followed by milling through a 1 mm screen and drying for another 4 h at 105°C. Neutral detergent fibre (NDF, with α-amylase) and acid detergent fibre (ADF) were estimated according to Van Soest et al. (1991). Iodine concentration in feed was measured by ICP-OES (Gregor and Fišera, 2002). Supplemental mixtures were analysed for total Gls using HPLC/UV-VIS according to ISO 9167-1 (1992).

Cows were milked twice daily (7.00 and 16.35 h). For pre- and post-milking care non-iodine sanitizing solutions (DEOSAN® uddercare (Johnson Diversey Manufacturing Facility, UK) and DEPROS DIP GEL (Diemer, s.r.o., SK)) were used. Milk yield was recorded at each milking. During the experimental period, samples of milk were taken from morning and evening milk three times a week, conserved with 2-bromo-2-nitropropane-1.3-diol (Bronopol; D and F Control Systems, Inc. USA) and cooled to 6°C. The composition of milk was analysed with an infrared analyser (Bentley Instruments 2000, Bentley Instruments Inc., USA). Milk iodine concentration was determined spectrophotometrically after dry alkaline mineralisation at 600°C by the Sandell-Kolthoff method (Bednář et al., 1964).

FA profile was determined as follows: extracted milk fat (50–60 mg) was dissolved in isooctane and homogenised in ultrasound. After the addition of sodium methanolate the mixture was heated under a reverse cooler. FA were released in the form of fatty acid methyl esters (FAMEs) which were separated using a gas chromatograph HP 4890D (Hewlett-Packard, USA) with capillary column DB–23 (60 m × 0.25 mm × 0.25 μm). The column was held at 100°C for 3 min after injection, the temperature was programmed at 10°C/min to 170°C, then the temperature was programmed at 4°C/min to 230°C and held at 250°C for 15 min, then the temperature was programmed at 5°C/min to 250°C. The injector and detector temperature was 270°C and 280°C, respectively. Nitrogen was used as a carrier gas. FAMEs were detected with the flame ionisation detector (FID) and identified according to the retention times using external standards of fatty acids Supelco 37 component FAME Mix (Supelco, USA) and Linoleic acid conjugated methyl ester (Sigma-Aldrich, Germany). For a list of determined fatty acids see Table 4.

Blood samples were obtained from the v*ena jugularis* three times a week after morning milking during the experimental period. The blood plasma was separated with a centrifuge (1 500 × g for 15 min, 4°C) and stored at –20°C until analyses. Blood plasma was analysed for thyroid hormones, i.e. triiodothyronine (T_3) and total thyroxine (T_4), by means of a radioimmunological method using commercially available kits (Total T3 RIA kit, Total T4 RIA kit, Immunotech, Prague, Czech Republic) according to the manufacturer's instructions.

Calculations and statistical analyses

For the calculation of indexes the following equations were used:
Index of atherogenicity (Ulbricht and Southgate, 1991):

$$AI = (C12 + 4 \times C14 + C16)/\text{sum of UFA}$$

Index of peroxidisability (Castellini et al., 2000):

$$PI = 0.025 \times \text{Mono} + \text{Di} + 2 \times \text{Tri} + 4 \times \text{Tetra} + 6 \times \text{Penta} + 8 \times \text{Hexa}$$

where:
Mono, Di, Tri, Tetra, Penta and Hexa = represent the weight percentages of monoenoic, dienoic, trienoic, tetraenoic, pentaenoic and hexaenoic FA, respectively

Index of desaturation (Chilliard and Ferlay, 2004):

DI = C18:1n9c/(C18:0 + C18:1n9c)

Index of spreadability of manufactured butter (Timmen, 1990):

SI = C 18:1n9c/C16:0

Data obtained in the experiment were analysed using the GLM procedure of SAS/STAT, Version 8 according to the following model (Kononoff and Hanford, 2006)

$$Y_{ijklm} = \mu + T_i + S_j + C_k(S_j) + P_l + W_m(P_l) + \varepsilon_{ijklm}$$

where:

μ = general mean
T_i = treatment effect (i = 2)
S_j = effect of square (j = 2)
$C_k(S_j)$ = effect of cow within square (k = 4)
P_l = period effect (l = 4)
$W_m(P_l)$ = effect of week within period (m = 3)
ε_{ijklm} = error term

For all statistical evaluations weekly means were used.

Table 2. The nutrient intake in dairy cows fed a diet based on either extruded rapeseed cake (R) or extruded full-fat soya (S)

Component	R[1]	S[1]	SE
Dry matter intake (kg/day)	18.88	18.86	0.280
PDIN[2] (kg/day)	1.52	1.58	0.030
PDIE[3] (kg/day)	1.59[a]	1.66[b]	0.011
NEL[4] (MJ/day)	115.97	117.01	1.920
Iodine intake (mg/day)	34.60	35.70	3.960
Gls intake[5] (mmol/day)	50.14	ND	0.988

[a,b]means in the same row followed by different superscripts differ ($P < 0.05$)
[1]R = diet based on extruded rapeseed cake; S = diet based on extruded full-fat soya
[2]digestible protein in the intestine when the rumen fermentable N supply is limiting
[3]digestible protein in the intestine when the rumen fermentable energy supply is limiting
[4]net energy of lactation
[5]glucosinolates
ND not detected

RESULTS

Nutrient intake and milk yield and composition

The nutrient intake is presented in Table 2. The intake of DM, PDIN and NEL did not differ significantly between groups ($P > 0.05$). The intake of PDIE was higher in S than in R ($P < 0.05$). The mean daily intake of iodine did not differ between groups ($P > 0.05$). The average total Gls content in extruded rapeseed cake was 25.3 µmol/g DM resulting in R in the average total Gls intake of 50.14 mmol/day. The content of Gls in a mixture containing extruded full-fat soya (S) was under the sensitivity level of the used analytical method.

Yield and composition of milk are given in Table 3. Milk yield and yield expressed in 4% FCM were significantly higher ($P < 0.05$) in S compared to R. The percentage of milk fat was higher ($P < 0.05$) and protein tended to be higher ($P > 0.05$) in R than in S. Due to the higher milk yield in S, protein yield was higher ($P < 0.05$) and fat yield tended to be higher ($P > 0.05$) in S in comparison with R.

Milk fatty acid profile

Saturated fatty acids

The fatty acid profile of milk fat is shown in Table 4. The total content of SFA tended to be

Table 3. Yield and composition of milk of cows fed a diet based on either extruded rapeseed cake (R) or extruded full-fat soya (S)

Component	R[1]	S[1]	SE
Milk yield (kg/day)	22.60[a]	24.68[b]	0.651
FCM[2] (kg/day)	22.68[a]	24.00[b]	0.754
Milk fat (g/kg)	40.10[a]	37.90[b]	1.470
Milk fat (kg/day)	0.91	0.94	0.040
Milk protein (g/kg)	32.20	31.70	0.450
Milk protein (kg/day)	0.73[a]	0.78[b]	0.019

[a,b]means in the same row followed by different superscripts differ ($P < 0.05$)
[1]R = diet based on extruded rapeseed cake; S = diet based on extruded full-fat soya
[2]4% fat corrected milk

Table 4. The fatty acid profile of milk fat of dairy cows fed a diet based on either extruded rapeseed cake (R) or extruded full-fat soya (S) (in g per 100 g of fatty acids determined)

Component	R[1]	S[1]	SE
C4:0	1.54^{a}	1.60^{b}	0.050
C6:0	1.42^{a}	1.50^{b}	0.044
C8:0	0.96^{a}	1.01^{b}	0.035
C10:0	2.25^{a}	2.42^{b}	0.112
C12:0	2.77^{a}	2.99^{b}	0.169
C14:0	10.45^{a}	11.12^{b}	0.271
C14:1	1.10^{a}	1.23^{b}	0.063
C16:0	28.04^{a}	29.70^{b}	0.743
C16:1	1.34	1.43	0.108
C18:0	13.87^{a}	11.99^{b}	0.753
C18:1n9t	4.16^{a}	4.52^{b}	0.270
C18:1n9c	28.01^{a}	24.91^{b}	0.793
C18:2n6t	0.39^{a}	0.42^{b}	0.025
C18:2n6c	2.34^{a}	3.49^{b}	0.129
C18:2 n-6	2.71^{a}	3.91^{b}	0.150
C18:3n6	0.02^{a}	0.03^{b}	0.002
C18:3n3	0.30^{a}	0.38^{b}	0.013
C18:2/9,11/	0.71^{a}	0.97^{b}	0.077
C18:2/10,12/	0.016^{a}	0.022^{b}	0.003
Total CLA[2]	0.73^{a}	0.99^{b}	0.077
C20:1	0.09^{a}	0.05^{b}	0.005
C20:4n6	0.14^{a}	0.17^{b}	0.006
C20:5n3	0.07^{a}	0.06^{b}	0.004
Other FAs[3]	ND	ND	
SFA	61.29	62.32	0.934
UFA	38.71	37.68	0.934
MUFA	34.71^{a}	32.14^{b}	0.892
PUFA	4.00^{a}	5.54^{b}	0.156
Short-chain[4]	8.94^{a}	9.52^{b}	0.344
Medium-chain[5]	40.93^{a}	43.47^{b}	1.042
Long-chain[6]	50.14^{a}	47.01^{b}	1.307
PUFA n-3	1.10^{a}	1.43^{b}	0.076
PUFA n-6	2.90^{a}	4.11^{b}	0.131
PUFA n-6/n-3	2.70^{a}	3.00^{b}	0.194
Indexes:			
Index of atherogenicity[7]	1.89^{a}	2.07^{b}	0.110
Index of peroxidisability[7]	5.97^{a}	7.55^{b}	0.174
Index of desaturation[7]	0.67	0.68	0.013
Index of spreadability[7]	1.01^{a}	0.85^{b}	0.077

[a,b]means in the same row followed by different superscripts differ ($P < 0.05$)
SFA = saturated fatty acids
UFA = unsaturated fatty acids
MUFA = monounsaturated fatty acids
PUFA = polyunsaturated fatty acids
[1]R = diet based on extruded rapeseed cake; S = diet based on extruded full-fat soya
[2]total CLA row is a sum of C18:2/9,11/ and of C18:2/10; 12/
[3]C22:4n6; C22:5n6; C22:5n3; C22:6n3 was under the limit of detection
[4]fatty acids with carbon length from C4 to C12
[5]fatty acids with carbon length from C14 to C16
[6]fatty acids with carbon length C18 and more
[7]see Materials and Methods

lower in R than in S ($P > 0.05$). After the inclusion of extruded rapeseed cake (R) into the diet the content of individual determined short- (C4:0, C6:0, C8:0, C10:0 and C12:0) and medium-chain FA (C14:0 and C16:0) as well as their sums decreased in comparison with feeding the extruded full-fat soya (S, $P < 0.05$). On the other hand, the content of C18:0 significantly increased in R compared to S ($P < 0.05$). The content of long-chain SFA greater than C20:0 was not determined.

Unsaturated fatty acids. The total content of UFA was not affected by the treatment ($P > 0.05$) but there was a tendency for a higher relative content of UFA in R than in S. The content of MUFA in R was significantly higher while the content of PUFA was lower than in S, respectively ($P < 0.05$). In medium-chain FA, the content of C14:1 was higher in S than in R ($P < 0.05$) while the content of C16:1 was not affected by the treatment ($P > 0.05$). The relative contents of long-chain UFA were positively influenced by the inclusion of extruded full-fat soya (S) into the diet ($P > 0.05$) except for C18:1n9c, C20:1 and C20:5n3, which were higher in R ($P > 0.05$). The relative contents of C18:2 and C18:3 isomers and metabolites in R were lower than in S ($P > 0.05$). Two main isomers of CLA (conjugated linoleic acid) were detected. The content of *cis*-9, *trans*-11 CLA isomer as well as the content of *trans*-10, *cis*-12 CLA isomer was significantly lower in R compared to S ($P > 0.05$).

Indexes. The index of atherogenicity and peroxidisability calculated for R was lower than in S ($P > 0.05$). The index of desaturation was almost similar in both groups and was not affected by the treatment ($P > 0.05$). The index of spreadability calculated for R was higher in comparison with S ($P > 0.05$).

Milk iodine content and plasma thyroid hormones levels. The concentration of iodine in milk in R was significantly lower than in S ($P > 0.05$) resulting in the lower daily iodine output in milk in R compared to S ($P < 0.05$, Table 5). Concentrations of thyroid hormones, triiodothyronine (T_3) and total thyroxine (T_4) estimated in blood plasma are shown in Table 5. Mean levels of T3 and T4 were similar in both groups and were not affected by the treatment ($P > 0.05$).

Table 5. Plasma thyroid hormones and milk iodine content in dairy cows fed a diet based on either extruded rapeseed cake (R) or extruded full-fat soya (S)

Hormone	R[1]	S[1]	SE
T3[2] (nmol/l)	1.81	1.81	0.048
T4[3] (nmol/l)	68.70	67.34	3.895
Iodine concentration and its output in milk			
Iodine (μg/l)	196.70[a]	367.00[b]	32.150
Iodine output (mg/day)	4.40[a]	9.20[b]	0.800

[a,b]means in the same row followed by different superscripts differ ($P < 0.05$)
[1]R = diet based on extruded rapeseed cake; S = diet based on extruded full-fat soya
[2]triiodothyronine
[3]thyroxine

DISCUSSION

Nutrient intake and milk yield and composition. In our experiment the average DMI of cows in both groups was almost identical ($P > 0.05$). Similar results were reported by Kudrna and Marounek (2006). Milk yield in R was significantly decreased in comparison with S. This is in agreement with e.g. Givens et al. (2003) or Solomon et al. (2000). On the other hand, Kudrna and Marounek (2006) did not find a difference in milk yield between cows receiving rapeseed cake and extruded soybeans. The lower milk fat content found in S is in accordance with findings of Kudrna and Marounek (2006) or Chouinard et al. (1997).

Fatty acid profile

Saturated fatty acids and oleic acid. The concentration of SFA determined in our study was not affected by the treatment but there was a tendency to higher levels in S ($P > 0.05$). The same findings were also reported by Komprda et al. (2000) or by Kudrna and Marounek (2006). The inclusion of extruded rapeseed cake (R) to the diet resulted in decreased concentration of palmitic acid (C16:0) and increased concentration of stearic acids (C18:0) in comparison with feeding extruded full-fat soya (S, $P < 0.05$). This is in accordance with the work of e.g. Kudrna and Marounek (2006) or Komprda et al. (2000). The secretion of oleic acid (C18:1n9c) can be increased either through its direct gut absorption and mammary secretion or mainly from its ruminal biohydrogenation followed by mammary desaturation of 18:0 (Chilliard et al., 2007). In our study, the concentration of oleic acid (C18:1n9c) was higher in R than in S ($P > 0.05$). These results are generally in agreement with Kudrna and Marounek (2006), who reported a tendency to increased levels of oleic acid in milk when feeding the rapeseed cake diet compared to feeding the extruded soybean diet.

Polyunsaturated fatty acids. The concentration of total PUFA and PUFA n-3 and n-6 series in the present experiment was lower in R than in S ($P > 0.05$). Similarly, Kudrna and Marounek (2006) reported a more pronounced positive effect of feeding extruded soybeans on the above-mentioned values than that of feeding rapeseed cake. On the other hand, Komprda et al. (2000) reported significant increases in total PUFA, PUFA n-6 series and PUFA n-6/n-3 ratio ($P > 0.05$) when feeding a diet with heat-treated rapeseed cakes in comparison with soybean meal diet while the concentration of PUFA n-3 was not affected by the treatment.

C18:2n6 and C18:3n3. The proportion of 18:2n6 in R was 2.73 g/100 g FA and was lower than 3.91 g/100 g FA determined in S ($P > 0.05$). This is in accordance with the results of Kudrna and Marounek (2006). The proportion of C18:3n3 FA was lower in R than in S ($P < 0.05$). This result is in accordance with the literature (reviewed e.g. by Chilliard and Ferlay, 2004). Nevertheless, Komprda et al. (2000) or Kudrna and Marounek (2006) did not find any effect of feeding heat-treated rapeseed cake or soybean meal on the concentration of C18:3n3. However, in the latter study, there was a tendency to lower levels of C18:3n3 FA in the rapeseed cake diet in comparison with the extruded soybean diet.

CLA. In the present experiment, two main CLA isomers were determined, *cis*-9, *trans*-11 C18:2 and *trans*-10, *cis*-12 C18:2. Both isomers of CLA were decreased in R in comparison with S ($P > 0.05$) although milk fat *trans*-10, *cis*-12 CLA concentrations remained low and only slightly exceeded the typical value for this isomer being 0.01 g/100 g FA (Dewhurst et al., 2006). Our findings are in accordance with those of Kudrna and Marounek (2006).

Indexes. The nutritional and physical properties of milk and dairy products and thus their acceptance by consumers are influenced by the length of the carbon chain of FA, their degree of (un)saturation and their positional distribution within the triacylgycerol molecules (Hillbrick and Augustin, 2002). There is a link between the intake of SFA and various biological markers for a cardiovascular disease risk. It was demonstrated that a higher consumption of myristic acid (14:0), palmitic acid (16:0), and lauric acid (12:0) increases concentrations of low-density lipoprotein, whereas a greater consumption of UFA has the reverse effect (e.g. Fernandez and West, 2005). Consequently, the index of atherogenicity (Ulbricht and Southgate, 1991) is used as a risk indicator for cardiovascular diseases. The index of atherogenicity calculated for R was lower than in S ($P > 0.05$). Our results are in discrepancy with Kudrna and Marounek (2006), who found a tendency to a decreased index of atherogenicity in the extruded soybean diet in comparison with the rapeseed cake diet. This discrepancy is probably caused by higher concentrations of lauric (C12:0) and myristic (C14:0) acids in rapeseed cake diet than in extruded soybean diet determined in their study contrary to our findings which probably arose from the higher content of rapeseed products (rapeseed cake and oil) in the diet used in our experiment.

The index of peroxidisability as an indicator of oxidative stability of milk fat was lower (i.e. better) in R than in S ($P > 0.05$). The same findings were reported by Kudrna and Marounek (2006). The index of spreadability calculated in our experiment was higher in R than in S and was close to that calculated in the above-mentioned study. This is in agreement with the McNamee et al. (2002), who described that the rapeseed-based diets resulted in an increased ratio of C18:1n9c/C16:0 and therefore produced softer butter fat.

Milk iodine and plasma thyroid hormones

In the present study, the mean iodine content in milk was 196.7 μg/l in R and 367.0 μg/l in S. These values are comparable with the iodine contents determined in milk samples in the Czech Republic in recent years (e.g. Kursa et al., 2007). On the other hand, our values are higher than those presented by Šustala et al. (2003), who compared the effect of iodine supplement on two types of diet, containing either rapeseed meal or soybean meal. This finding is in accordance with other studies done in the Czech Republic that indicate an increase in iodine concentration in bovine milk during the last years (e.g. Kursa et al., 2007).

Although the iodine intake in both groups was close (34.6 mg/day and 35.7 mg/day in R and S, respectively), the iodine concentration in milk in R was significantly lower in comparison with S ($P > 0.05$). A similar effect was also described in other studies (e.g. Šustala et al., 2003; Hejtmánková et al., 2006). This effect is associated with the strumigenous effect of Gls that are present in rapeseed cake as mentioned in the study of Laarveld et al.

(1981a), who reported that dietary Gls levels reduced iodine content in a curvilinear manner. In their subsequent study, Laarveld et al. (1981b) found that feeding low-Gls products, containing 11.5 μmol of total Gls/g DM resulting in the daily Gls intake of 14–47 mmol, did not change the iodine content in milk. On the other hand, feeding low-Gls rapeseed meal with 4.0–15.5 μmol of total Gls/g DM at higher levels to dairy cows (i.e. Gls intake of 37 to 63 mmol/day) reduced the milk iodine content. This is in agreement with our results. The mean daily Gls intake in R in our study was 50.14 mmol and resulted in a significant decrease in iodine concentration in milk in R in comparison with the control diet (S) where Gls were not detected. The levels of T3 and T4 were not affected by the treatment in our experiment, which is in accordance with literature (e.g. Zech et al., 1995 or Šustala et al., 2003).

CONCLUSION

Rapeseed products have become dietary components frequently used in dairy cow nutrition as an adequate substitution of soybean products. The aim of the study was to compare the effect of extruded rapeseed cake and extruded full-fat soya in diets of dairy cows on changes in the milk fatty acid profile. Direct comparison of the two products showed that the inclusion of extruded rapeseed cake into the diet of dairy cows increased the content of MUFA and decreased the content of palmitic acid (C16:0) and PUFA in comparison with feeding extruded full-fat soya ($P > 0.05$) while the total content of SFA and UFA was not influenced ($P > 0.05$). Further, it is necessary to take into account a decrease in the concentration of iodine in milk due to glucosinolate content when low-glucosinolate rapeseed products are used instead of soybean in the diet.

REFERENCES

Amman H. (1996): Wirtschaftlichkeit des Rapsschrotes als Futtermittel. Agrarforsch, 3, 200–203.

AOAC (1984): Official Methods of Analysis, Association of Official Analytical Chemists, 14th ed. Arlington, Virginia, USA, 1141 pp.

Bednář B., Röhling S., Vohnout S. (1964): Contribution to determination of protein iodine in blood serum. Československý Farmář, 13, 203–209. (in Czech)

Berg J.N., Padgitt D., McCarthy B. (1988): Iodine concentrations in milk of dairy cattle fed various amounts of iodine as ethylenediamine dihydroiodide. Journal of Dairy Science, 71, 3283–3291.

Burel C., Boujard T., Escaffre A.M., Kaushik S.J., Boeuf G., Mol K.A., Van der Geyten S., Kuhn E.R. (2000): Dietary low glucosinolate rapeseed meal affect thyroid status and nutrient utilization in rainbow trout (*Oncorhynchus mykiss*). British Journal of Nutrition, 83, 653–664.

Castellini C., Dal Bosco A., Bernardini M. (2000): Improvement of lipid stability of rabbit meat by vitamin E and C administration. Journal of the Science of Food and Agriculture, 81, 46–53.

Dahl L., Opsahl J.A., Meltzer H.M., Julshamn K. (2003): Iodine concentration in Norwegian milk and dairy products. British Journal of Nutrition, 90, 679–685.

Dewhurst R.J., Shingfield K.J., Lee M.R.F., Scollan N.D. (2006): Increasing the concentrations of beneficial polyunsaturated fatty acids in milk produced by dairy cows in high-forage systems. Animal Feed Science and Technology, 131, 168–206.

Fernandez M.L., West K.L. (2005): Mechanisms by which dietary fatty acids modulate plasma lipids. Journal of Nutrition, 135, 2075–2078.

Focant M., Mignolet E., Matatu B., Legrand A., Givron C., Vanbelle M. (1994): Fatty acid composition of the milk modified by feeding extruded rapeseed to dairy cows. In: Proc. 45th Annu. Mtg. of European Association of Animal Production, Edinburgh, Scotland, UK, 114 pp.

Givens D.I., Allison R., Blake J.S. (2003): Enhancement of oleic acid and vitamin E concentrations of bovine milk using dietary supplements of whole rapeseed and vitamin E. Animal Research, 52, 531–542.

Gregor T., Fišera M. (2002): The ICP-OES method for determination of iodine in foods and medicaments. In: ICS-UNIDO Workshop, January 14–16, Brno, CR, 330–331.

Hejtmánková A., Kuklík L., Trnková E., Dragounová H. (2006): Iodine concentrations in cow's milk in Central and Northern Bohemia. Czech Journal of Animal Science, 51, 189–195.

Hill R. (1991): Rapeseed meal in the diet of ruminants. Nutrition Abstracts and Reviews, 61, 139–155.

Hillbrick G., Augustin M.A. (2002): Milk fat characteristics and functionality: Opportunities for improvement. Australian Journal of Dairy Technology, 57, 45–51.

Homolka P., Harazim J., Třináctý J. (2007): Nitrogen degradability and intestinal digestibility of rumen undegraded protein in rapeseed, rapeseed meal and extracted rapeseed meal. Czech Journal of Animal Science, 52, 378–386.

Chilliard Y., Ferlay A. (2004): Dietary lipids and forages interactions on cow and goat milk fatty acid composition and sensory properties. Reproduction Nutrition Development, 44, 467–492.

Chilliard Y., Glasser F., Ferlay A., Bernard L., Rouel J., Doreau M. (2007): Diet, rumen biohydrogenation and nutritional quality of cow and goat milk fat. European Journal of Lipid Science and Technology, 109, 828–855.
Chouinard P.Y., Le'Vesque J., Girard V., Brisson G.J. (1997): Dietary soybeans extruded at different temperatures: Milk composition and in situ fatty acid reactions. Journal of Dairy Science, 80, 2913–2924.
ISO 9167-1 (1992): Rapeseed – Determination of glucosinolates content, Part 1: Method using high-performance liquid chromatography, 9 pp.
Jahreis G., Steinhart H., Pfalzgraf A., Flachowsky G., Schöne F. (1996): Effect of rapeseed oil feeding to dairy cows on fatty acid composition of butterfat. Zeitschrift fur Ernahrungswissenschaft, 35, 185–190.
Jensen R.G. (2002): Invited review: the composition of bovine milk lipids: January 1995 to December 2000. Journal of Dairy Science, 85, 295–350.
Komprda T., Dvořák R., Suchý P., Fialová M., Šustová K. (2000): Effect of heat treated rapeseed cakes in dairy cow diet on yield, composition and fatty acid pattern of milk. Czech Journal of Animal Science, 45, 325–332.
Kononoff P.J., Hanford K.J. (2006): Technical note: Estimating statistical power of mixed models used in dairy nutrition experiments. Journal of Dairy Science, 89, 3968–3971.
Kudrna V., Marounek M. (2006): The feeding rapeseed cake and extruded soybean on the performance of lactating cows and the fatty acid pattern of milk. Journal of Animal and Feed Sciences, 15, 361–370.
Kursa J., Herzig I., Trávníček J., Kroupová V. (2007): Iodine content in food of animal origin. In: Sborník VIII. konference Jódový deficit a jeho prevence v ČR, 6.3. 2007, České Budějovice, CR, 7–10. (in Czech)
Laarveld B., Brockman R.P., Christensen D.A. (1981a): The effects of Tower and Midas rapeseed meals on milk production and concentration of goitrogens and iodine in milk. Canadian Journal of Animal Science, 61, 131–139.
Laarveld B., Brockman R.P., Christensen D.A. (1981b): The effect of the level in canola meal concentrate on milk iodine and thiocyanate content and thyroid function in dairy cow. Canadian Journal of Animal Science, 61, 625–632.
Lock A.L., Shingfield K.J. (2004): Optimising milk composition. In: Kebreab E., Mills J., Beever D.E. (eds.): Dairying-Using Science to Meet Consumers'. British Society of Animal Science. Nottingham University Press, Loughborough, UK, 107–188.
McNamee B.F., Fearon A.M., Pearce J. (2002): Effect of feeding oilseed supplements to dairy cows on ruminal and milk fatty acid composition. Journal of the Science of Food and Agriculture, 82, 677–684.
Miller J.K., Ramsey N., Madsenl F.C. (1988): The trace elements. In: The Ruminant Animal-Digestive Physiology and Nutrition. D.C. Church. Englewood Cliffs, Prentice-Hall, UK, 342–401.
Solomon R., Chase L.E., Ben-Ghedalia D., Bauman D.E. (2000): The effect of nonstructural carbohydrate and addition of full fat extruded soybeans on the concentration of conjugated linoleic acid in the milk fat of dairy cows. Journal of Dairy Science, 83, 1322–1329.
Sorensen P. (1962): Studies of thyroid function in cattle and pig. In: Use of Radioisotopes in Animal Biology and Medical Sciences. Academic Press, New York, 1, 455 pp.
Šustala M., Třináctý J., Kudrna V., Illek J., Šustová K. (2003): The effect of iodine supplementation on its output and thyroid gland status in dairy cows on a diet containing rapeseed meal. Czech Journal of Animal Science, 48, 170–180.
Tempelman R.J. (2004): Experimental design and statistical methods for classical and bioequivalence hypothesis testing with an application to dairy nutrition studies. Journal of Animal Science, 82, E162–E172.
Timmen H. (1990): Characterization of milk fat hardness in farm milk by parameters of fatty acid composition. Kieler Milchwirtschaftliche Forschungsberichte, 42, 129–138.
Tripathi M.K., Mishra A.S., Misra A.K., Mondal D., Karim S.A. (2001): Effect of substitution of groundnut with high glucosinolate mustard (*Brassica juncea*) meal on nutrient utilisation, growth, vital organ weight and blood composition of lambs. Small Ruminant Research, 39, 261–267.
Ulbricht T.L.V., Southgate D.A.T. (1991): Coronary heart disease: seven dietary factors. Lancet, 338, 985–992.
Van Soest P.J., Robertson J.B., Lewis B.A. (1991): Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. Journal of Dairy Science, 74, 3583–3597.
Zech K., Wemheuer W., Paufler S. (1995): Zum einsatz von Rapsextraktionsschrot in der Milchkuhfutterung. Tierarztliche Umschau, 50, 46–52.

Received: 2008–09–19
Accepted after corrections: 2009–02–03

Corresponding Author

Ing. Aleš Veselý, Research Institute for Cattle Breeding, Ltd., Department of Animal Nutrition Physiology, Vídeňská 699, 691 23 Pohořelice, Czech Republic
Tel. +420 519 426 000, fax +420 519 424 548, e-mail: ales.vesely@seznam.cz