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The effect of cattle breed, season and type of diet on the fatty acid profile of raw milk

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Abstract. The aim of the study was to determine the effect of cow breed, season and type of diet on the fatty acid (FA) profile of raw milk. A 2-year study was conducted on bulk milk samples collected from eight herds consisting of Czech Fleckvieh (CF, four herds) and Holstein (H, four herds) breeds. One half of the herds of each breed was grazed (G), while the other half was not (N). Samples were collected twice in winter (W) and twice in summer (S). Milk yield in CF (5385.50 kg) was lower than in H (7015.15 kg, $P < 0.05$). The effect of breed was found in odd-chain, branch-chain and hypercholesterolemic FAs ($P < 0.05$). The content of fat was lower in summer (S) than in winter (W), being 3.71 and 3.91 g 100 g^{-1}, respectively ($P < 0.05$). The proportion of saturated and polyunsaturated FAs was lower in S than in W ($P < 0.05$). The content of monounsaturated FAs was higher in S (30.69 g 100 g^{-1}) than in W (27.72 g 100 g^{-1}, $P < 0.05$). Milk yield in grazing herds (G, 5197.50 kg) was lower ($P < 0.05$) than in non-grazing herds (N, 7203.75 kg). The sum of saturated and hypercholesterolemic FAs was lower and the sum of monounsaturated and odd-chain FAs was higher in G than in N ($P < 0.05$). Content of conjugated linoleic acid (CLA) and C18:3n3 was higher in G (0.93 and 0.64 g 100 g^{-1}) than in N (0.42 and 0.39 g 100 g^{-1}, respectively, $P < 0.001$).

1 Introduction

Bovine milk contains on average 4 % of fat that is from 97 to 98 % composed of triacylglycerols (Jensen, 2002). Milk fat can contain up to 400 different fatty acids (FAs; Jensen, 2002) that are usually grouped according to saturation of their carbon chain into saturated (SFAs), monounsaturated (MUFAs) and polyunsaturated (PUFAs) fatty acids. Bovine milk typically contains 70 % SFAs, 25 % MUFAs and 5 % PUFAs (Grummer, 1991; Shingfield et al., 2008). From the view of human health, attention has recently also been paid to so-called hypercholesterolemic FAs (HCFAs, C12:0, C14:0 and C16:0), which increase deposition of fat in the vascular walls and are related to atherosclerotic diseases (Jensen, 2002), and to odd- and branch-chain FAs (OCFAs and BCFAs, respectively), which are capable of inhibiting cancer cell proliferation and differentiation as well as inducing apoptosis in a number of cancer cell lines (Adamska et al., 2014).

Many factors can affect the FA composition of bovine milk fat, including breed (Adamska et al., 2014; Samková et al., 2014), parity (Stádník et al., 2013) or stage of lactation (Kirchnerová et al., 2013), as well as animal factors and diet composition (reviewed by Kalač and Samková, 2010), season (Frelich et al., 2012; Adler et al., 2013), geographical location (Collomb et al., 2008), access to fresh grazing

Table 1. Basic information about environment of studied dairy cow herds.

Farm no.	Breed	*n*	Milk yield/ lactation (kg)	Altitude (m)	Annual rainfall (mm)	Mean annual temperature (°C)
1	CF	315	6445	440	650	7.90
2	CF	68	6735	360	700	7.00
7	CF	73	4526	550	900	4.50
8	CF	75	3836	680	1140	7.40
	x	132.8	5385.5	507.5	847.5	6.7
	SD	121.5	1424.0	138.9	222.9	1.52
3	H	125	6790	250	700	7.80
4	H	66	5638	520	720	4.80
5	H	439	7511	390	650	5.50
6	H	318	8124	286	670	9.60
	x	237	7015.8	361.5	685.0	6.9
	SD	172.4	1068.1	121.2	31.1	2.20
Total	*x*	184.9	6200.6	434.5	766.3	6.8
	SD	148.9	1455.1	143.7	171.0	1.75

n, number of cows per herd; *x*, mean; SD, standard deviation; CF, Czech Fleckvieh; H, Holstein.

(Frelich et al., 2012; Shingfield et al., 2013), grazing sward type (reviewed by Roca Fernandez and Gonzalez Rodriguez, 2012), silage type (Kalač and Samková, 2010), feeding of cereal and oil seeds, and oil supplementation in feed (Angulo et al., 2012; Stergiadis et al., 2014; Siurana and Calsamiglia, 2016) as nutritional and management factors. The above-mentioned studies showed the possibility of altering FA profile of milk fat. However, as Coppa et al. (2013) pointed out, the majority of studies investigating the effect of diet and animal-related factors on milk FA profile were controlled trials not always reflecting common practice in commercial farms or applying measurements of farming practices not suitable on farms.

Thus, the aim of the study was to determine the effect of the two predominant breeds reared in the Czech Republic and the effects of season and feeding management on the fatty acid profile of raw bovine milk.

2 Material and methods

2.1 Herd management and diet

A 2-year study was conducted on bulk milk samples collected from eight commercial dairy herds consisting of Czech Fleckvieh (CF, four herds) and Holstein (H, four herds) dairy cows. The average herd size was 185 ± 149 (from 66 to 439) dairy cows and the average milk yield was 6200.6 ± 1455.1 kg (from 3836 to 8124 kg) (see Table 1 also for details about selected farms' environmental characteristics). Cows were fed diets consisting of maize silages, clover–grass haylages, meadow hay, locally available feedstuffs, concentrate and mineral mixtures according to relevant milk yield and standard requirements. One half of the herds of each breed was grazed (G) during the summer season, while the other half was not (N). Composition of diets for each herd is given in Table 2.

2.2 Sampling and analysis

Cows were milked twice a day, and samples were collected regularly two times in the winter (W) and two times in the summer (S) period. In each group a total of 32 bulk milk samples were examined. Data concerning daily milk performance were obtained from animal records kept from milk recording kept by the Czech-Moravian Breeders' Corporation.

The content of fat was measured on MilkoScan 133B (Foss Electric, Denmark). Fatty acids (FAs) were determined by gas chromatography (GLC) using a Varian 3800 (Varian Techtron, USA) according to the following conditions:

- column: Omegawax 250 (30 m, 0.25 mm, 0.25 mm);
- detector: flame ionisation detector;
- temperature of column: 70 °C for 3 min; 30 °C min^{-1} up to 150 °C; 3.0 °C min^{-1} up to 240 °C;
- temperature of injection: 250 °C;
- temperature of detector: 250 °C;
- helium flow: 1.8 mL min^{-1};
- injection: 1 µL split ratio 10.

Milk fat was extracted with petroleum ether from freeze-dried milk samples. FAs of isolated fat were re-esterified to their methyl esters by methanolic solution of potassium

Table 2. Composition of diets (kg day^{-1}, as fed basis) of dairy cows used in experimental herds.

		Farm no.							
		1	2	7	8	3	4	5	6
Summer diet	Grass and herbal pasture			50	50	25	40		
	Meadow hay			3	2.5				
	Clover–grass haylage					12	5		
	Maize silage					10	5		
	Supplemental mixture			2	2.5	4	0.5		
	Mineral mixture			0.1	0.15	0.15	0.1		
	Brewer's draff				5				
Winter diet	GPS silage	4		40		22		20	
	Maize silage	10	17						17
	Clover–grass haylage	9	19		35	15	25	14	13
Year-round diet	Barley straw					0.7			0.5
	Meadow hay	1.5	1.5	5	5		3	0.7	0.5
	Mineral mixture	0.2	0.1	0.1	0.2	0.8	0.1	0.2	0.5
	Brewer's draff	7			2		12		
	Molasses				0.6				
	Supplemental mixture	1.5	4.5	2.5	2.5	4.7	0.5	2.6	6
	Sugarbeet chippings		2			0.9		1.4	7

GPS silage: silage from whole maize plant in vax maturity.

hydroxide. The identification of FA methyl esters was carried out using analytical standards (SUPELCO, USA) and acetonitrile chemical ionisation mass spectrometry (Varian MS 4000 detector). Calibration was performed using a quantitative analytical standard (SUPELCO, USA). The proportions of individual FAs were calculated from the ratio of their peak area to the total area of all the observed FAs. The conjugated linoleic acid (CLA) refers to 9-*cis*, 11-*trans* and 9-*trans*, 11-*cis* isomers of C18:2 (the GLC method does not allow for distinguishing between the two isomers). Also, isomers of C18:1 are not distinguished.

2.3 Statistical analysis

The GLM procedure of the SAS v. 9 program package (SAS Institute Inc., Cary, NC, USA) was used for the calculation. Multi-factor analysis of variance with fixed effects as breed, season and feeding was used for statistical evaluation of the data set according to following model:

$$y_{ijk} = \mu + b_i + s_j + f_k + e_{ijk},$$

where y_{ijk} is the independent variable, μ is the general mean, b_i is the effect of breed ($i = 2$), s_j is the effect of season ($j = 2$), f_k is the effect of feeding ($k = 2$), and e_{ijk} is the random effect.

3 Results

3.1 Effect of the breed

Milk yield, content of milk fat and its FA composition in dependence on breed, season and type of feeding is presented in Table 3. Milk yield in CF was 5385.50 kg and was lower than the milk yield in H (7015.15 kg, $P < 0.001$). The concentration of milk fat was higher in CF than in H ($P < 0.05$). In general, contents of FA groups in the CF and H breeds, respectively, determined in our study were as follows: SFAs, 65.34 and 67.09 g 100 g^{-1}; MUFAs, 29.09 and 28.49 g 100 g^{-1}; and PUFAs, 3.89 and 3.82 g 100 g^{-1}. The content of MUFAs did not differ significantly between breeds ($P > 0.05$). Although the sum of PUFAs was not influenced by the breed ($P > 0.05$), the following FAs differed significantly between CF and H cows: C18:2n6, C18:2, C18:3n3, C20:3, C20:4 and C20:5 ($P < 0.05$). Further, content of CLA was higher in CF (0.8 g 100 g^{-1}) than in H (0.55 g 100 g^{-1}) ($P < 0.01$). A sum of OCFAs was higher in CF than in H ($P < 0.05$), mainly due to higher values of C15:0 and C17:0 in CF than in H ($P < 0.05$). Similarly, higher content of iso C14:0, iso 15:0 and iso 16:0 in CF than in H ($P < 0.05$) resulted in a higher sum of BCFAs in CF in comparison to H ($P < 0.05$).

Table 3. Effect of cattle breed, season and type of feeding on the fatty acid profile (g 100 g^{-1} of total fatty acids) of milk fat.

	Breed		Season		Type of feeding			*P* value		
	CF ($n = 32$)	H ($n = 32$)	S ($n = 32$)	W ($n = 32$)	G ($n = 32$)	N ($n = 32$)	SEM	Breed	Season	Feeding
Milk yield (kg)	5385.50	7015.75	6200.63	6200.63	5197.50	7203.75	77.887	< 0.001	1.000	< 0.001
Fat (g 100 g^{-1})	3.90	3.72	3.71	3.91	3.89	3.74	0.06	0.022	0.015	0.035
Fatty acid profile (g 100 g^{-1} of total fatty acids)										
C4:0	2.65	2.58	2.40	2.83	2.64	2.59	0.089	0.584	0.001	0.719
C6:0	1.98	1.91	1.85	2.03	1.86	2.03	0.067	0.500	0.061	0.079
C8:0	1.30	1.23	1.22	1.31	1.176	1.36	0.046	0.318	0.222	0.007
C10:0	3.12	2.91	2.96	3.07	2.696	3.34	0.116	0.217	0.515	< 0.001
C10:1	0.27	0.27	0.26	0.28	0.26	0.29	0.011	0.844	0.154	0.041
C11:0	0.04	0.04	0.04	0.04	0.02	0.05	0.006	0.916	0.701	0.005
C12:0	3.44	3.19	3.29	3.34	3.72	2.90	0.138	0.212	0.821	< 0.001
C12:1	0.10	0.10	0.08	0.12	0.11	0.09	0.011	0.889	0.037	0.268
C13:0	0.11	0.11	0.11	0.11	0.09	0.13	0.004	0.574	0.910	< 0.001
iso C14:0	0.13	0.11	0.12	0.12	0.14	0.10	0.004	0.002	1.000	< 0.001
C14:0	11.33	10.92	11.21	11.04	10.57	11.68	0.272	0.289	0.677	0.006
C14:1	0.84	0.90	0.87	0.88	0.83	0.91	0.028	0.131	0.820	0.052
iso C15:0	0.33	0.29	0.31	0.30	0.34	0.28	0.009	0.006	0.488	< 0.001
anteiso C15:0	0.51	0.49	0.54	0.46	0.53	0.47	0.012	0.182	< 0.001	0.001
C15:0	1.21	1.14	1.20	1.15	1.14	1.22	0.024	0.045	0.167	0.025
C16:0 iso	0.30	0.27	0.29	0.28	0.29	0.28	0.007	< 0.001	0.245	0.622
C16:0	29.98	33.06	31.14	31.89	31.02	32.02	0.607	< 0.001	0.395	0.2495
C16:1	1.76	1.91	1.92	1.75	1.81	1.86	0.049	0.043	0.478	0.023
iso C17:0	0.51	0.46	0.50	0.47	0.52	0.46	0.021	0.100	0.039	0.402
anteiso C17:0	0.49	0.47	0.49	0.46	0.48	0.48	0.011	0.173	0.101	0.968
C17:0	0.69	0.63	0.68	0.64	0.69	0.64	0.017	0.015	0.084	0.037
C18:0	6.76	6.84	6.14	7.46	7.14	6.47	0.641	0.930	0.151	0.470
C18:1*	26.15	24.50	26.73	23.91	26.49	24.15	0.693	0.098	0.020	0.005
C18:2n6	2.14	2.43	2.20	2.37	2.18	2.39	0.084	0.015	0.178	0.090
C18:2	0.29	0.18	0.25	0.22	0.16	0.31	0.018	< 0.001	0.375	< 0.001
C19:0	0.09	0.08	0.07	0.10	0.10	0.08	0.005	0.237	0.003	0.007
C19:1	0.12	0.10	0.10	0.12	0.13	0.08	0.006	0.006	0.071	< 0.001
C18:3n3	0.62	0.41	0.59	0.44	0.64	0.39	0.049	0.003	0.036	< 0.001
C18:2 (9,11 – CLA)	0.80	0.55	0.71	0.64	0.93	0.42	0.062	0.007	0.403	< 0.001
C20:0	0.20	0.17	0.19	0.19	0.21	0.16	0.007	0.029	0.954	< 0.001
C20:1	0.27	0.25	0.23	0.29	0.28	0.23	0.017	0.391	0.016	0.043
C20:2	0.13	0.12	0.08	0.18	0.13	0.13	0.025	0.864	0.010	0.932
C20:3n6+C21:0	0.08	0.09	0.07	0.10	0.07	0.10	0.006	0.091	0.004	0.012
C20:4n6	0.11	0.14	0.12	0.13	0.10	0.15	0.011	0.036	0.675	0.010
C20:4n3	0.04	0.02	0.03	0.04	0.04	0.03	0.004	0.008	0.011	0.043
C20:5n3	0.05	0.04	0.04	0.05	0.04	0.05	0.003	0.004	0.059	0.006
C22:0	0.07	0.06	0.05	0.07	0.07	0.05	0.004	0.033	0.004	< 0.001
C22:5n3	0.08	0.07	0.06	0.09	0.08	0.07	0.006	0.297	< 0.001	0.594
C22:6n3 (DHA)	ND	ND	ND	ND	ND	ND				
C24:0	0.05	0.07	0.04	0.09	0.09	0.04	0.019	0.470	0.040	0.098

Table 3. Continued.

	Breed		Season		Type of feeding			*P* value		
	CF ($n = 32$)	H ($n = 32$)	S ($n = 32$)	W ($n = 32$)	G ($n = 32$)	N ($n = 32$)	SEM	Breed	Season	Feeding
Milk yield (kg)	5385.50	7015.75	6200.63	6200.63	5197.50	7203.75	77.887	< 0.001	1.000	< 0.001
Fat (g 100 g^{-1})	3.90	3.72	3.71	3.91	3.89	3.74	0.06	0.022	0.015	0.035
Sums of fatty acids										
SFA	65.34	67.09	64.90	67.53	64.74	67.69	0.717	0.088	0.012	0.005
MUFA	29.92	28.49	30.69	27.72	30.33	28.09	0.667	0.134	0.002	0.021
PUFA	3.89	3.82	3.66	4.06	3.95	3.77	0.129	0.702	0.031	0.351
UFA	33.82	32.31	34.35	31.78	34.27	31.86	0.682	0.124	0.010	0.015
PUFA + CLA	4.69	4.37	4.37	4. 70	4.88	4.19	0.175	0.202	0.190	0.008
UFA + CLA	34.62	32.86	35.06	32.42	35.20	32.28	0.716	0.089	0.011	0.005
OCFA	2.11	1.98	2.08	2.01	2.03	2.06	0.037	0.011	0.210	0.465
BCFA	1.89	1.73	1.87	1.75	1.91	1.71	0.051	0.025	0.111	0.006
HCFA	44.74	47.17	45.64	46.27	44.50	47.42	0.798	0.035	0.584	0.012

CF, Czech Fleckvieh; H, Holstein; S, summer season; W, winter season; G, grazed herds; N, non-grazed herds; C18:1*: includes both cis- and trans- isomers; CLA, conjugated linoleic acid (9-*cis*, 11-*trans* and 11-*cis*, 9-*trans* C18:2); DHA, docosahexaenoic acid; ND, not detected; SFA, saturated fatty acids; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids; UFA, unsaturated fatty acids; OCFA, odd-chain fatty acids; BCFA, branched-chain fatty acids (iso and anteiso); HCFA, hypercholesterolemic fatty.

3.2 Effect of the season

The concentration of milk fat was lower during the summer season (S; 3.71 g 100 g^{-1}) than in the winter season (W; 3.91 g 100 g^{-1}) ($P < 0.05$). The content of total SFAs was lower in S (64.9 g 100 g^{-1}) than in W (67.53 g 100 g^{-1}, $P < 0.05$). No effect of season was observed on the content of HCFA in our study ($P > 0.05$). The content of MUFAs was higher in S than in W, being 30.69 and 27.72 g 100 g^{-1}, respectively ($P < 0.05$), mainly due to significantly increased values of C18:1 in S compared to W ($P < 0.05$). The content of PUFAs in S (3.66 g 100 g^{-1}) was lower than in W (4.06 g 100 g^{-1}, $P < 0.05$); however, content of C18:2n6 and CLA was not affected by the season.

3.3 Effect of the type of feeding

Milk yield in grazing herds (G, 5197.50 kg) was lower ($P < 0.05$) than in non-grazing herds (N, 7203.75 kg). Content of fat was higher in G than in N ($P < 0.05$). The sum of SFAs in G (64.74 g 100 g^{-1}) was lower than in N (67.69 g 100 g^{-1}, $P < 0.05$) mainly due to significant differences in C8:0, C10:0, C11:0, C13:0, and C14:0 ($P < 0.05$), even if major SFAs such as C16:0 and C18:0 did not differ between G and N feeding systems. The content of MUFAs was higher in G than in N ($P < 0.05$), mainly due to higher proportion of C18:1 in G (26.49 g 100 g^{-1}) in comparison to N (24.15 g 100 g^{-1}, $P < 0.05$). Furthermore, higher contents of minor FAs, such as C19:1 and C20:1 in G ($P < 0.05$), contributed to differences in total MUFAs as well. Although the content of PUFAs in our study was not affected by the type of feeding ($P > 0.05$), higher content of CLA and C18:3n3 in G compared to N was observed ($P < 0.001$). The content of BCFAs was higher in G (1.91 g 100 g^{-1}) than in N (1.71 g 100 g^{-1}, $P < 0.05$).

4 Discussion

Our findings concerning milk yield and concentration of milk fat are in agreement with data characterising an ordinary population of dairy cows of these two breeds bred in the Czech Republic (e.g. Wolfová et al., 2007; Ducháček et al., 2014). Contents of SFAs, MUFAs and PUFAs determined in our study are within the range that has been recently reported for these FA groups in H and CF cows (Samková et al., 2014; Stádník et al., 2013; Ducháček et al., 2014).

As mentioned earlier, breed belongs to factors affecting FA composition of milk fat, as proved in recent studies (e.g. Palladino et al., 2010; Van Eijndhoven et al., 2011; Samková et al., 2014); however, many authors agree that the effect of breed on FA profile is minor compared with the effects of diet (Garnsworthy et al., 2006; Ferlay et al., 2011; Nantapo et al., 2014). According to Kelsey et al. (2003) and Roca Fernandez and Gonzalez Rodriguez (2012) breed contributes less than 1 % of the variation in milk FAs. This was also confirmed in our study because we found significant breed effects only in OCFAs, BCFAs and HCFAs and some individual medium- and long-chain SFAs and MUFAs and CLA ($P < 0.05$). Our findings are in agreement with studies performed on the same breeds (Samková et al., 2014). Minor breed effects on medium- or long-chain SFAs and MUFAs or on HCFAs have also been found in other studies (Morales et al., 2000; Drackley et al., 2001; White et al., 2001; Ferlay et al., 2006).

Season is considered a substantial source of variation in the FA composition of milk fat (Frelich et al., 2012; Adler et al., 2013). In our study, the content of total SFAs was lower in S than in W ($P < 0.05$). Similar findings were reported by Adler et al. (2013), who found higher proportions of total SFAs and most short- and medium-chain SFAs in milk from the indoor feeding season compared to the outdoor feeding season. A positive effect of season on SFA proportion has also been proved by Lindmark-Månsson et al. (2003), Collomb et al. (2008) and Ozcan et al. (2015), with the highest differences mainly in C16:0 and C18:0. Frelich et al. (2012) described lower content of short-chain SFAs (C4:0 − C10:0) and C12:0 in S compared to W in herds kept indoors ($P < 0.05$). Seasonal variations among SFAs were also noted by Adamska et al. (2014).

Increased levels of C18:1 in S compared to W ($P < 0.05$) are in agreement with Adler et al. (2013); however, in their study, significant differences in individual MUFAs were also noted in C14:1 and C16:1 FAs, which were not affected by the season in our study. On the other hand, we observed seasonal variation in few minor FAs such us C12:1 and C20:1. Lock and Garnsworthy (2003) and Wiking et al. (2010) also mentioned higher content of C18:1 in summer milk. Among individual PUFAs, significant differences were observed in C18:3n3 and also in some minor FAs ($P < 0.05$). Higher values of C18:3n3 in S were also reported in other studies (Lindmark-Månsson et al., 2003; Lock and Garnsworthy, 2003; Collomb et al., 2008; Wiking et al., 2010; Adler et al., 2013). On the other hand, Frelich et al. (2012) and Ozcan et al. (2015) found no effect of season on C18:3n3 content. In our study, content of C18:2n6 and CLA was not affected by the season. Similar findings were reported by Lindmark-Månsson et al. (2003), Frelich et al. (2012) and Ozcan et al. (2015). In contrast, Collomb et al. (2008) and Adler et al. (2013) observed a positive effect of the outdoor/summer season on content of these two FAs ($P < 0.05$). Discrepancies in the effect of season on FA profile as discussed above can be at least partly explained by different management of herds during the summer season, when pasture or feeding of fresh forage to cows kept indoors can be applied. This is also the case in our study because one half of each of the studied herds was grazed during the summer, while the other half was not. This fact can influence seasonal differences in FA profile; however, it represents the common practice in the Czech Republic and thus characterises the FA profile of milk fat in this part of the year.

The breeding of the two most common dairy breeds, H and CF, in the Czech Republic relies on two feeding strategies: a pasture-based feeding system with a seasonal pasture from May to October followed by silage feeding indoors for the rest of the year, and a silage-based feeding system with the indoor silage feeding without any access to pasture throughout the year (Frelich and Šlachta, 2011). Concerning the total SFAs, our results are in agreement with many studies comparing pasture-based and silage-based feeding systems (Frelich et al., 2009, 2012; Kirchnerová et al., 2013; Shingfield et al., 2013); however, there are some differences in the effect of feeding system on individual SFAs. In the study of Frelich et al. (2009) content of C4:0 was lower in the indoor feeding season; furthermore, they found significant differences in C16:0 and C18:0. Similarly, in their subsequent study Frelich et al. (2012) mentioned lower content of C12:0, C14:0, C15:0 and C16:0 and higher content of C18:0 in grazing herds in comparison to indoor kept herds ($P < 0.05$). According to Dewhurst et al. (2006) and Coppa et al. (2013), a lower amount of C16:0 in milk from feeding of fresh herbage is a well-known and well-predicted trend that is attributed to a lower C16:0 proportion in herbage in comparison to maize silage (Elgersma et al., 2006).

The lower content of HCFAs in G is in disagreement with Kirchnerová et al. (2013), who did not find significant differences in total HCFAs. The content of MUFAs was higher in G than in N ($P < 0.05$) mainly due to higher proportion of C18:1, C19:1 and C20:1. This is in agreement with Chilliard et al. (2009), Frelich et al. (2012) and Shingfield et al. (2013). Also, Kirchnerová et al. (2013) proved a higher content of MUFAs in a pasture-based feeding system. On the other hand, Adamska et al. (2014) did not find differences in total MUFAs but confirmed the positive effect of pasture on C18:1 FAs in Polish indigenous cattle.

The content of PUFAs in our study was not affected by the type of feeding ($P > 0.05$). In contrast to our results, significantly higher content of PUFAs was determined in many studies (Frelich et al., 2009; Kirchnerová et al., 2013; Samková et al., 2014). Discrepancy also exists in the effect of the type of feeding on n3 and n6 FAs. According to Kirchnerová et al. (2013), the content of n3 and n6 FAs was not affected by the feeding system, while Frelich et al. (2009) found in grazed cows higher content of C18:2n6 but lower content of C18:3n3 ($P < 0.05$). In their subsequent study (Frelich et al., 2012), both C18:2n6 and C18:3n3 were higher in grazed herds ($P < 0.05$). Similarly, Shingfield et al. (2013) and Samková et al. (2014) mentioned higher concentrations of 18:2n-6 and 18:3n-3 when feeding cows fresh lucerne or leaving them to graze, respectively, while Dewhurst et al. (2006) and Chilliard et al. (2007) described an increase in 18:3n-3. Our findings concerning the effects of fresh forage on increasing CLA content are consistent with a number of studies (Lock and Garnsworthy, 2003; Dewhurst et al., 2006; Chilliard et al., 2007; Frelich et al., 2009, 2012; Kalač and Samková, 2010; Roca Fernández and González Rodríguez, 2012; Shingfield et al., 2013; Samková et al., 2014).

In addition to our study, higher content of BCFAs in grazed herds has been reported by Ferley et al. (2008), Frelich et al. (2009), Slots et al. (2009) and Kirchnerová et al. (2013). Furthermore, changes in BCFAs that originate from rumen fermentation can be well predicted by an increase in fresh herbage and hay and a decrease in

maize silage and concentrates in the cows' diet (Coppa et al., 2013) because high-neutral detergent fibre diets (such as fresh herbage-based diet) favour ruminal populations of cellulolytic bacteria instead of the amylolytic bacteria favoured by starch-rich diets (Vlaeminck et al., 2006). Furthermore, the FA profile of milk fat can be influenced by the FA composition of pastures, which is dependent upon species, variety, growing conditions and forage maturity, as well as by grazing management strategies implemented at the farm level such as timing of cutting or grazing (Chouinard et al., 1998; Dewhurst et al., 2003; Elgersma et al., 2006; Ferlay et al., 2006).

5 Conclusions

In conclusion, this study confirmed that breed has only a minor influence on the FA profile of milk fat. Seasonal variability was observed in 14 FAs. In the summer season the content of saturated and polyunsaturated FAs was lower and content of monounsaturated FAs was higher than in the winter season. A positive effect was observed mainly in C18:1 FAs. Cow feeding had a major effect on milk FA composition. The variability in FA proportion was observed in 26 FAs. Pasture, compared to year-round feeding based on silages, decreased the contents of saturated and hypercholesterolemic FAs and increased the proportion of C18:1, 18:3n-3 and conjugated linoleic acid (CLA).

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References

Adamska, A., Rutkowska, J., Tabaszewska, M., and Białek, M.: Milk of Polish Red and White cows as a source of nutritionally valuable fatty acids, Arch. Tierzucht, 57, 1–10, 2014.

Adler, S. A., Jensen, S. K., Govasmark, E., and Steinshamn, H.: Effect of short-term versus long-term grassland management and seasonal variation in organic and conventional dairy farming on the composition of bulk tank milk, J. Dairy Sci., 96, 5793–5810, 2013.

Angulo, J., Hiller, B., Olivera, M., Mahecha, L., Dannenberger, D., Nuernberg, G., Losande, B., and Nuernberg, K.: Dietary fatty acid intervention of lactating cows simultaneously affects lipid profiles of meat and milk, J. Sci. Food Agric., 92, 2968–2974, 2012.

Chilliard, Y., Martin, C., Rouel, J., and Doreau, M.: Milk fatty acids in dairy cows fed whole crude linseed, extruded linseed, or linseed oil, and their relationship with methane output, J. Dairy Sci., 92, 5199–5211, 2009.

Chilliard, Y., Glasser, F., Ferlay, A., Bernard, L., Rouel, J., and Doreau, M.: Diet, rumen biohydrogenation and nutritional quality of cow and goat milk fat, Eur. J. Lipid Sci. Tech., 109, 828–855, 2007.

Chouinard, P. Y., Corneau, L., Bauman, D. E., Butler, W. R., Chilliard, Y., and Drackley, J. K.: Conjugated linoleic acid content of milk from cows fed different sources of dietary fat, J. Anim. Sci., 76, 233, 1998.

Collomb, M., Bisig, W., Bütikofer, U., Sieber, R., Bregy, M., and Etter, L.: Fatty acid composition of mountain milk from Switzerland: comparison of organic and integrated farming systems, Int. Dairy J., 18, 976–982, 2008.

Coppa, M., Ferlay, A., Chassaing, C., Agabriel, C., Glasser, F., Chilliard, Y., Borreani, G., Barcarolo, R., Baars, T., Kusche, D., Harstad, O. M., Verbič, J., Golecký, J., and Martin, B.: Prediction of bulk milk fatty acid composition based on farming practices collected through on-farm surveys, J. Dairy Sci., 96, 4197–4211, 2013.

Dewhurst, R. J., Scollan, N. D., Lee, M. R. F., Ougham H. J., and Humphreys M. O.: Forage breeding and management to increase the beneficial fatty acid content of ruminant products, P. Nutr. Soc., 62, 329–336, 2003.

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

Drackley, J. K., Beaulieu, A. D., and Elliott, J. P.: Responses of milk fat composition to dietary fat or nonstructural carbohydrates in Holstein and Jersey cows, J. Dairy Sci., 84, 1231–1237, 2001.

Ducháček, J., Stádník, L., Ptáček, M., Beran, J., Okrouhlá, M., Čítek, J., and Stupka, R.: Effect of cow energy status on hypercholesterolemic fatty acids proportion in raw milk, Czech J. Food Sci., 32, 273–279, 2014.

Elgersma, A., Tamminga, S., and Ellen, G.: Modifying milk composition through forage, Anim. Feed Sci. Tech., 131, 207–225, 2006.

Ferlay, A., Martin, B., Pradel, P., Coulon, J. B. and Chilliard, Y.: Influence of grass-based diets on milk fatty acid composition and milk lipolytic system in Tarentaise and Montbéliarde cow breeds, J. Dairy Sci., 89, 4026–4041, 2006.

Ferlay, A., Agabriel, C., Sibra, C., Journal, C., Martin, B., and Chilliard, Y.: Tanker milk variability in fatty acids according to farm feeding and husbandry practices in a French semi-mountain area, Dairy Sci. Technol., 88, 193–215, 2008.

Ferlay, A., Glasser, F., Martin, B., Andueza, D., and Chillard, Y.: Effects of feeding factors and breed on cow milk fatty acid composition: Recent data, Bulletin UASVM, Vet. Med., 1, 137–145, 2011.

Frelich, J. and Šlachta, M.: Impact of seasonal grazing on udder health of cows, Acta Univ. agric. Silvic. Mendel. Brun., 59, 53–58, 2011.

Frelich, J., Šlachta, M., Hanuš, O., Špička, J., and Samková, E.: Fatty acid composition of cow milk fat produced on low-input mountain farms, Czech J. Anim. Sci., 54, 532–539, 2009.

Frelich, J., Šlachta, M., Hanuš, O., Špička, J., Samková, E., Węglarz, A., and Zapletal, P.: Seasonal variation in fatty acid composition of cow milk in relation to the feeding system, Anim. Sci. Pap. Rep., 30, 219–229, 2012.

Garnsworthy, P. C., Masson, L. L., Lock, A. L., and Mottram, T. T.: Variation of milk citrate with stage of lactation and de novo fatty acid synthesis in dairy cows, J. Dairy Sci., 89, 1604–1612, 2006.

Grummer, R. R.: Effect of feed on the composition of milk fat, J. Dairy Sci., 74, 3244–3257, 1991.

Jensen, R. G.: The composition of bovine milk lipids: January 1995 to December 2000, J. Dairy Sci., 85, 295–350, 2002.

Kalač, P. and Samková, E.: The effects of feeding various forages on fatty acid composition of bovine milk fat: A review, Czech J. Anim. Sci., 55, 521–537, 2010.

Kelsey, J. A., Corl, B. A., Collier, R. J., and Bauman, D. E.: The effect of breed, parity, and stage of lactation on conjugated linoleic acid (CLA) in milk fat from dairy cows, J. Dairy Sci., 86, 2588–2597, 2003.

Kirchnerová, K., Foltys, V., and Špička, J.: Impact of lactation stage on milk fat fatty acids profile in grazing dairy cows, J. Microb. Biotech. Food Sci., 2, 1164–1174, 2013.

Lindmark-Månsson, H., Fondén, R., and Pettersson, H. E.: Composition of Swedish dairy milk, Int. Dairy J., 13, 409–425, 2003.

Lock, A. L. and Garnsworthy, P. C.: Seasonal variation in milk conjugated linoleic acid and Δ^9-desaturase activity in dairy cows, Livest. Prod. Sci., 79, 47–59, 2003.

Morales, M. S., Palmquist, D. L., and Weiss, W. P.: Milk fat composition of Holstein and Jersey cows with control or depleted copper status and fed whole soyabeans or tallow, J. Dairy Sci., 83, 2112–2119, 2000.

Nantapo, C. T. W., Muchenje, V., and Hugo, A.: Atherogenicity index and health-related fatty acids in different stages of lactation from Friesian, Jersey and Friesian × Jersey cross cow milk under a pasture-based dairy system, Food Chem., 146, 127–133, 2014.

Ozcan, T., Yaslioglu, E., Kilic, I., and Simsek, E.: The influence of the season and milking time on the properties and the fatty acid composition of the milk in different dairy cattle farms, Mljekarstvo, 65, 9–17, 2015.

Palladino, R. A., Buckley, F., Prendiville, R., Murphy, J. J., Callan, J., and Kenny, D. A.: A comparison between Holstein-Friesian and Jersey dairy cows and their F-1 hybrid on milk fatty acid composition under grazing conditions, J. Dairy Sci., 93, 2176–2184, 2010.

Roca Fernandez, A. I. and Gonzalez Rodriguez, A.: Effect of dietary and animal factors on milk fatty acids composition of grazing dairy cows: A review, Iran., J. Appl. Anim. Sci., 2, 97–109, 2012.

Samková, E., Čertíková, J., Špička, J., Hanuš, O., Pelikánová, T., and Kváč, M.: Eighteen-carbon fatty acids in milk fat of Czech Fleckvieh and Holstein cows following feeding with fresh lucerne (Medicago sativa L.), Anim. Sci. Pap. Rep., 32, 209–218, 2014.

Shingfield, K. J., Chilliard, Y., Toivonen, V., Kairenius, P., and Givens, D. I.: Trans fatty acids and bioactive lipids in ruminant milk, Adv. Exp. Med. Biol., 606, 3–65, 2008.

Shingfield, K. J., Bonnet, M., and Scollan, N. D.: Recent developments in altering the fatty acid composition of ruminant-derived foods, Animal, 7, 132–162, 2013.

Siurana, A. and Calsamiglia S.: A metaanalysis of feeding strategies to increase the content of conjugated linoleic acid (CLA) in dairy cattle milk and the impact on daily human consumption, Anim. Feed Sci. Tech., 217, 13–26, 2016.

Slots, T., Butler, G., Leifert, C., Kristensen, T., Skibsted, L. H., and Nielsen, J. H.: Potentials to differentiate milk composition by different feeding strategies, J. Dairy Sci., 92, 2057–2066, 2009.

Stádník, L., Ducháček, J., Okrouhlá, M., Ptáček, M., Beran, J., Stupka, R., and Zita, L.: The effect of parity on the proportion of important healthy fatty acids in raw milk of Holstein cows, Mljekarstvo, 63, 195–202, 2013.

Stergiadis, S., Leifert, C., Seal, C. J., Eyre, M. D., Steinshamn, H., and Butler, G.: Improving the fatty acid profile of winter milk from housed cows with contrasting feeding regimes by oilseed supplementation, Food Chem., 164, 293–300, 2014.

Van Eijndhoven, M. H. T., Hiemstra, S. J., and Calus, M. P. L.: Short communication: milk fat composition of 4 cattle breeds in the Netherlands, J. Dairy Sci., 94, 1021–1025, 2011.

Vlaeminck, B., Fievez, V., Cabrita, A. R. J., Fonseca, A. J. M., and Dewhurst, R. J.: Factors affecting odd- and branched-chain fatty acids in milk: A review, Anim. Feed Sci. Tech., 131, 389–417, 2006.

White, S. L., Bertrand, J. A., Wade, M. R., Washburn, S. P., Green, J. R., and Jenkins, T. C.: Comparison of fatty acid content of milk from Jersey and Holstein cows consuming pasture or a total mixed ration, J. Dairy Sci., 84, 2295–2301, 2001.

Wiking, L., Theil, P. K., Nielsen, J. H., and Sorensen, M. T.: Effect of grazing fresh legumes or feeding silage on fatty acids and enzymes involved in the synthesis of milk fat in dairy cows, J. Dairy Res., 77, 337–342, 2010.

Wolfová, M., Wolf, J., Kvapilík, J., and Kica, J.: Selection for profit in cattle: I. Economic weights for purebred dairy cattle in the Czech Republic, J. Dairy Sci., 90, 2442–2455, 2007.