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Institute of Genetics and Animal Breeding, Jastrzębiec, Poland

Quality of goat pasture in less-favoured areas (LFA) of the Czech Republic and its effect on fatty acid content of goat milk and cheese*

Bohuslav Čermák[1], Václav Král[1], Jan Frelich[1], Lucie Boháčová[1], Barbora Vondrášková[1], Jiří Špička[1], Eva Samková[1], Milan Podsedníček[1], Andrzej Węglarz[2], Joanna Makulska[2], Piotr Zapletal[2]**

[1] Faculty of Agriculture, University of South Bohemia in České Budějovice, Czech Republic

[2] University of Agriculture in Cracow, Department of Cattle Breeding, Al. Mickiewicza 24/28, 30-059 Cracow, Poland

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The aim of the study was to assess the quality of pastures located in less-favoured areas (LFA) of Czech Republic, to evaluate the influence of that quality on the content of fatty acids of milk in grazing goats and in farm natural cheese made of their milk. Samples of forage were collected in 2008 and 2009, on 5 July, 9 August, 6 September and 4 October. Goat milk samples were taken on the same days of both years and additionally on May 31. The highest content of protein and fat of the forage dry matter and, consequently, the highest feeding value of pasture were found in July and October. It was associated with a high content of clovers and herbs in the available herbage. During grazing the content of saturated fatty acids (SFA) of goat milk fat continuously decreased while the trend for the content of monounsaturated fatty acids (MUFA) was opposite. A significant increase in herb of the total crop observed in autumn contributed to a highest content of polyunsaturated fatty acids (PUFA) in fat of goat milk. The fatty acid profile of goat cheese was related to that of the milk. Thus, a high content of PUFA, including CLA, observed in milk of grazing goats guarantees that the cheese made of that milk fulfills the requirements for functional foods.

KEY WORDS: goat / milk fatty acids / cheese / pasture quality / less-favoured areas

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**Corresponding author: cermak@zf.jcu.cz

An important part of farming in less-favoured areas (LFA) is ruminant keeping. Sustainable pastures located in LFA offer good conditions for seasonal grazing. A high-quality pasture should consist of 60-70% of grasses, 20-25% of clovers and 10-15% of herb species with a favourable biological effect. Especially rich in the beneficial components are among others, *Taraxacum officinale, Plantago lanceolata, Alchemilla vulgaris, Achillea millefolium, Sanguisorba officinalis,* [Čerešňáková *et al.* 1999, Klimeš *et al.* 2004, 2007, Pozdíšek *et al.* 2004]. They are characterized by antibacterial, astringent, mildly expectorant, haemostatic, ophthalmic, refrigerant, anti-diarrhoea, styptic and tonic properties [Foster and Duke 1990, Phillips and Foy 1990, Chevallier 1996, Zhu *et al.* 1999, Mrkvička *et al.* 2002, Hejduk 2007]. Some of them are also reach in Ca, Na and Mn [Huxley 1992, Kuusela and Hytti 2001, Mrkvička and Veselá 2002, Skládanka 2005].

The mentioned properties result in a substantial increase of the use of herbs and their products as medical preparations and food supplements both for animals and for humans. Nutrients from pasture not only positively affect digestion and health of grazing animals but are also transferred into milk. Special attention, from human health point of view, is attributed to functional fatty acids, such as omega-3 and conjugated linoleic acid (CLA), found in considerable amounts in pasture herbage. The studies on the influence of botanical composition of the pasture on the quality of milk and cheese obtained from cows are relatively numerous [e.g. Collomb *et al.* 2002, 2002a, Innocente *et al.* 2002, Leiber *et al.* 2005]. Also, there are quite many data on the relationship between the type of the diet and the composition of dairy products manufactured from milk of sheep and goats maintained under intensive conditions and/or in southern countries [e.g. Morand-Fehr *et al.* 2000, Chilliard and Ferlay 2004, Morand-Fehr 2005, Pulina *et al.* 2006, Mele *et al.* 2007, Sanz Sampelayo *et al.* 2007, Eknaes *et al.* 2009, Goetsch *et al.* 2011]. However, such information regarding the goats kept under extensive conditions, in more temperate climate, is almost lacking [Žan *et al.* 2006].

Facing the above, the aim of this study was to assess the quality of pastures located in less-favoured areas of Czech Republic and to investigate the influence of that quality on the content of fatty acids in milk of grazing goats and in the ripened cheese named “Farm goat natural cheese – ecological product” made of their milk.

Material and methods

The study was carried out in 2008 and 2009 on the pastures of the ecological goat farm located in the West Bohemian region near Karlovy Vary, Czech Republic. This region is classified as belonging to a category of less-favoured areas. The farm is situated in the Special Bird Protection Area (Act. No. 100/2004 Coll.) in which a specific grazing regimen was applied. The examined stands were located at an altitude of 450 to 800 m above sea level and were not fertilized artificially. The average temperatures and rainfalls in the area of farm location are presented in Table 1.

Table 1. The average air temperature and rainfall in the area of goat farm location

Year	Month					
	May	June	July	August	September	October
	Average temperature (°C)					
2008	9.7	13.9	15.7	16.1	10.9	7.5
2009	11.5	14.3	16.4	13.8	13.7	12.9
	Average rainfall (mm)					
2008	65.8	134.4	85.0	53.1	52.3	56.1
2009	73.0	91.9	144.4	124.5	63.5	78.9

Monitoring of the botanical structure of the pastures included the estimation of the content of grasses, clovers and other plants. Samples of forage were collected from 7 plots (10 m^2 each) on 5 July, 9 August, 6 September and 4 October, in both years of study. They were dried at the room temperature to a constant weight and then ground in a laboratory cutting mill SM 100 (RETSCH). Aliquots of the dried samples were ashed at 550°C. The samples collected at the same date were mixed together. Cell wall constituents (crude fibre, NDF, ADF, ADL) were analysed in ANKOM fibre bag analyser. Dry matter, protein and fat content were determined by Weende analysis with a default laboratory procedure. Feeding value (in scale from 0 to 5) was evaluated following the method described by Klimeš [1997, 2004].

The pastures were grazed by a flock of goats in 2-4 lactation stage. Samples of milk were collected on 31 May, 5 July, 9 August, 6 September and 4 October in both years of study. The analyses of milk composition, including fatty acid content, were performed in accordance with the ISO standards. Fatty acids were determined by a gas-chromatography (GLC) using an apparatus Varian 3800 (VARIAN TECHTRON, USA). Milk fat was extracted with petroleum ether from freeze-dried milk samples. Fatty acids of isolated fat were re-esterified to their methyl esters by methanolic solution of potassium hydroxide. The identification of fatty acid methyl esters was carried out using the analytical standards (SUPELCO, USA) and acetonitrile chemical ionization mass spectrometry (VARIAN MS 4000 detector). The collected milk was used to produce the ripened cheese named "Farm goat natural cheese – ecological product". After 14 days from manufacturing cheese samples were analysed for the fatty acid profile.

Statistical analysis of two years average results included estimation of means, standard errors and standard deviations as well as performing t-tests and Friedman ANOVA-tests by means of STATISTICA package [StatSoft CR s r.o., 2008].

Results and discussion

Botanical and nutrient composition of pasture

Characteristics of botanical composition of the stands in days of sample collection is presented in Figure 1. In July proportion of herbs and clovers to grasses was almost equal and in October even higher. The highest share of herbs alone was found in October and then in July. In August and in September almost no clover was observed.

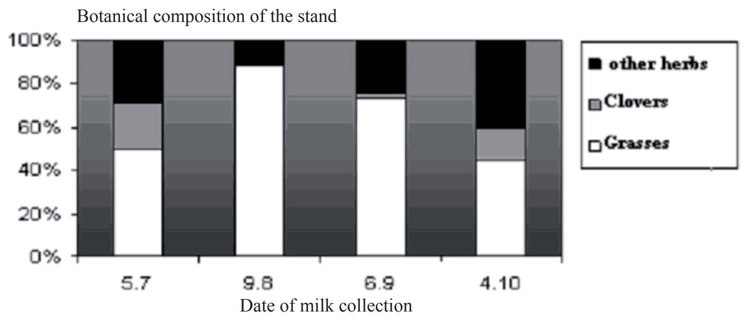

Fig. 1. Botanical composition of the pasture stand on the day of sample collection.

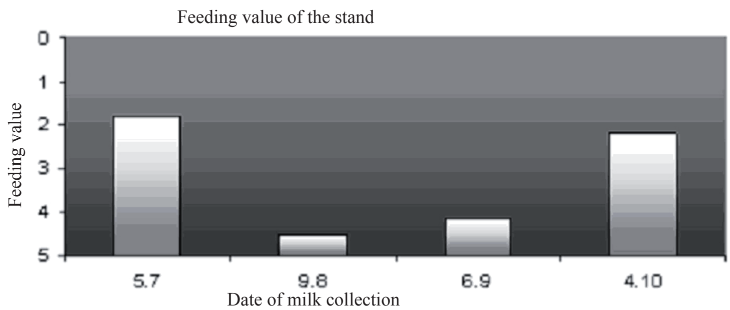

Fig. 2. Feeding value of the pasture stand on the day of sample collection.

Table 2. Chemical composition of forage samples (g/100g DM)

Year	Quality	Ash	Fat	CP	CF	NDF	ADF	ADL	OM	NFEC
2008	poor	6.98	1.27	7.36	27.90	65.53	35.65	2.74	87.26	50.73
2009	good	7.71	1.83	9.46	22.30	50.46	30.92	3.35	86.59	53.00

DM – dry matter, CP – crude protein, CF – crude fibre, NDF – neutral detergent fibre, ADF – acid detergent fibre, ADL – acid detergent lignin, OM – organic matter, NFEC – nitrogen free extractive.

The share of herbs and clovers was closely related to the feeding value of the pasture which was the highest in July and October and the lowest in August (Fig. 2).

The grazed forage was analysed also for nutrient composition and digestibility. Higher content of crude protein (CP) and lower content of crude fibre, NDF and ADF in forage dry matter, found in 2009 year (Tab. 2), corresponded to higher digestibility of organic matter as well as higher rumen degradability of crude protein (CP) (Tab. 3). Better quality of forage obtained in 2009, compared to 2008, most probably resulted from more advantageous weather conditions – higher air temperature and higher rainfall (Tab. 1).

The highest values of CP content in pasture dry matter were found in July and in October (Fig. 3). The latter significantly exceeded the previous measurements.

Table 3. Average forage yield, organic matter digestibility (OMD) and rumen crude protein degradability (CPD)

Year	Forage yield (t/ha)	OMD (%)	CPD (%)
2008	3.05	71	65
2009	3.35	85	68

It was probably caused by a recent re-growth of pasture. The content of CP in pasture dry matter was associated with the proportion of clovers and herbs and the feeding value of the stand (Fig. 1 and 2). Fat content in forage dry matter of (Fig. 4) roughly corresponded to the total proportion of herbs and clovers (Fig. 1) and to the feeding value of the stand (Fig. 2). As can be seen from Figure 5, fibre constituted approximately 30% of the absolute dry matter during the almost whole period studied.

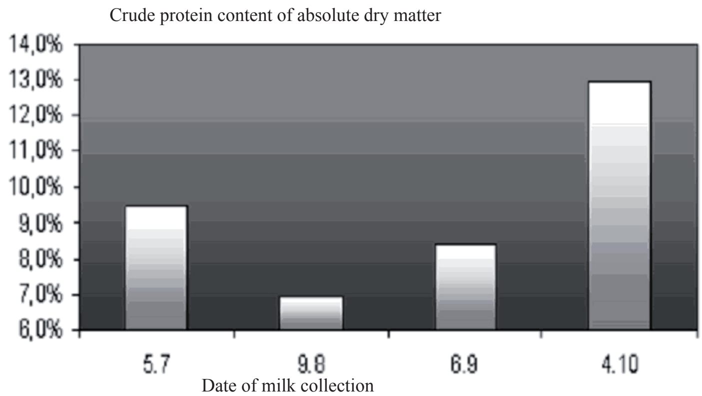

Fig. 3. Crude protein content of pasture crops on the day of sample collection.

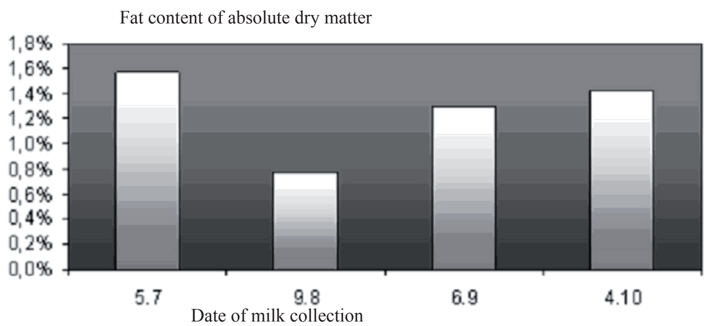

Fig. 4. Fat content of pasture crops on the day of sample collection.

Only in October this value was noticeably lower. This can be explained by the fact that in October the monitored goats grazed the pasture recently overgrown after mowing. Until then the goats grazed only on the poor quality vegetation areas that could not be harvested by a tractor-operated mower.

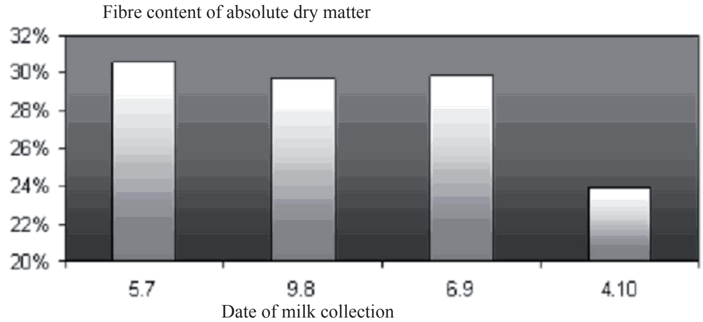

Fig. 5. Fibre content of pasture crops on the day of sample collection.

Milk yield and milk fat content

A noticeable decrease of the average daily milk yield observed during grazing should be related mainly to the progress of lactation (Fig. 13). The lowest daily milk yield found in October was accompanied by a high fat content both in milk fat and in pasture dry matter as well as by a high feeding value of the pasture stand (Fig. 6, 4 and 2). Similarly, Strzałkowska *et al.* [2009, 2010] reported an increased milk fat content at the final stage of goat lactation. The highest and the lowest milk fat content observed, respectively, in July and August, was associated with the highest and the lowest fat content in pasture dry matter and the highest and the lowest feeding value of the stand, respectively. Sanz Sampelayo *et al.* [2007] indicated that fat contained in goats' feed affected the quantity and composition of milk fat more than of other feed components. So, the increased milk fat content in autumn, found in the present study, resulted probably partly from the higher fat content in pasture forage and from the increased milk solids at the end of lactation, as well. The changes in milk composition, observed at this time, could also be attributed to a lower air temperature and a shorter day.

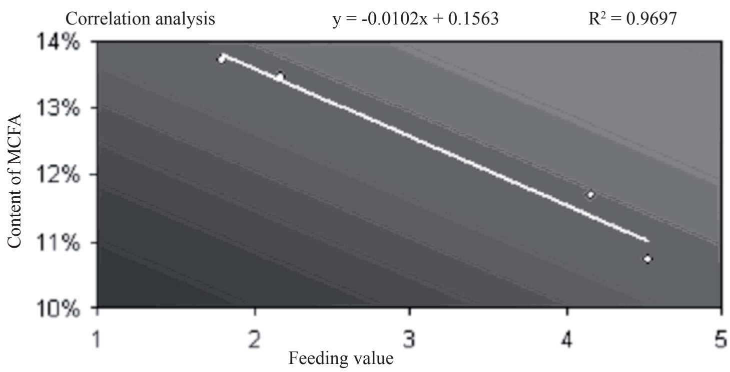

Fig. 6. Correlation between feeding value of the pasture stand and the content of medium-chain fatty acids (MCFA) in goat milk fat.

Fatty acids profile

The botanical and chemical composition of pasture herbage and the stage of lactation of the studied goats affected not only total milk fat content and but also the content of particular milk fatty acids. For example, the highest content of medium-chain fatty acids (MCFA) of milk was associated with the highest feeding value of the stand (Fig. 6) and with the highest CP and fat content in pasture crops, found in July and in October (Fig. 3 and 4). Similar reports on the effect of the increased fat content of goat diet on the content of milk fatty acids were found in the papers by Chilliard and Ferlay [2004], Sanz Sampelayo *et al.* [2007] and Jóźwik *et al.* [2010].

Saturated fatty acids (SFA)

The content of SFA of goat milk fat decreased noticeably after moving from winter feed to fresh forage and then a continuous decline during grazing was observed (Fig. 7). The highest difference was found between May and August; afterwards a decline remained rather moderate. Generally, the content of SFA decreased in the studied period by more than 7.5% of total milk fat. Statistical differences in the content of SFA of milk fat at the days of sample collection are presented in Table 4. It can be seen that

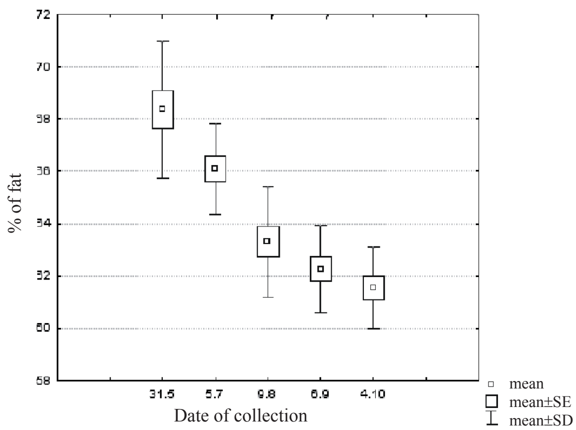

Fig. 7. Saturated fatty acid (SFA) content of goat milk fat on the day of sample collection.

Table 4. Results of Friedman ANOVA-test for saturated fatty acid (SFA) content of goat milk fat

Date of collection	Rank sum	Differences of rank sums (significant values are bolded)					Critical value of Friedman test
		31.5.	5.7.	9.8.	6.9.	4.10.	(α=0.05)
31.5.	61	0	5	**25**	**36**	**44**	
5.7.	56	5	0	20	**31**	**39**	
9.8.	36	**25**	20	0	11	19	22.0
6.9.	25	**36**	**31**	11	0	8	
4.10.	17	**44**	**39**	19	8	0	

each value differed significantly from all others, except for the preceding and the next ones. The only exception is the measurement made in August, which failed to prove a difference against measurement made in October because towards the end of the grazing season (last three measurements) a decrease of SFA content was diminished. The decrease of SFA content found from May to October could result jointly from the changes in forage composition and from the progress of lactation. The effect of lactation stage on the concentration of fatty acids in goat milk was observed also by Strzałkowska *et al.* [2009, 2010].

Monounsaturated fatty acids (MUFA)

Contrary to SFA, the content of MUFA in goat milk fat increased significantly from May to September (Fig. 8). Then a slight decline in October was observed. The increase of MUFA content amounted to almost 7% of the total milk fat, which was comparable to the decrease of SFA content. The statistically significant differences between the measurements of MUFA content of milk fat at the days of sample collection, presented in Table 5, were considerably similar to those obtained for SFA (Tab. 4).

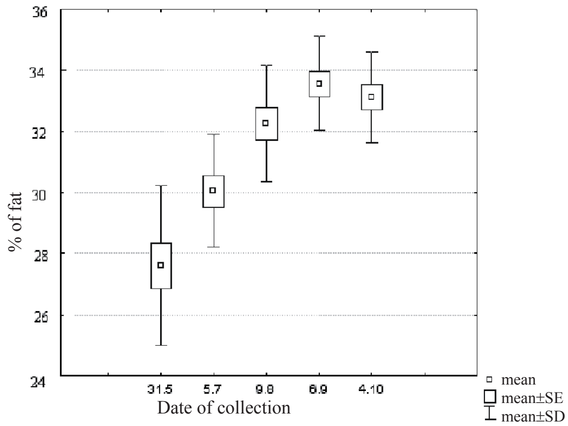

Fig. 8. Monounsaturated fatty acid (MUFA) content of goat milk fat on the day of sample collection.

Table 5. Results of Friedman ANOVA-test for monounsaturated fatty acid (MUFA) content of goat milk fat

Date of collection	Rank sum	Differences of rank sums (significant values are bolded)					Critical value of Friedman test
		31.5.	5.7.	9.8.	6.9.	4.10.	(α=0.05)
31.5.	15	0	10	**28**	**42**	**40**	
5.7.	25	10	0	18	**32**	**30**	
9.8.	43	**28**	18	0	14	12	22.0
6.9.	57	**42**	**32**	14	0	2	
4.10.	55	**40**	**30**	12	2	0	

Polyunsaturated fatty acids (PUFA)

There was no continuous trend in the content of PUFA (including CLA) in goat milk fat in the studied months (Fig. 9 and 10). After moving from winter feeding to pasture, the level of PUFA (including CLA) slightly decreased. Their noticeable increase observed in October corresponded with only slight increase of fat content of pasture crops (Fig. 4). The total PUFA and CLA contents recorded in October were significantly higher from all other measurements except for total PUFA in August and CLA in September (Tab. 6 and 7). The obtained results are in accordance with the findings of Strzałkowska *et al.* [2009] who observed a significant increase of PUFA content towards the end of lactation.

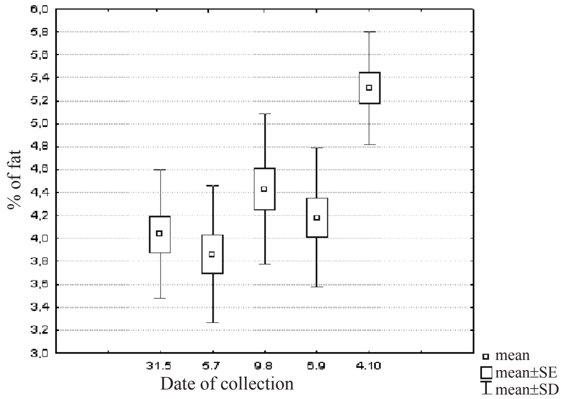

Fig. 9. Polyunsaturated fatty acid (PUFA) content of goat milk fat on the day of sample collection.

Table 6. Results of Friedman ANOVA-test for polyunsaturated fatty acid (PUFA) content of goat milk fat

Date of collection	Rank sum	Differences of rank sums (significant values are bolded)					Critical value of Friedman test
		31.5.	5.7.	9.8.	6.9.	4.10.	(α=0.05)
31.5.	33	0	10	9	2	**29**	
5.7.	23	10	0	19	12	**39**	
9.8.	42	9	19	0	7	20	22.0
6.9.	35	2	12	7	0	**27**	
4.10.	62	**29**	**39**	20	**27**	0	

Ratio of n-3/n-6 PUFA

PUFA belong to fatty acids of a favourable effect on human health, however, a proper ratio of n-3/n-6 acid groups should be maintained, with the maximum value being 1/5 [Samková *et al.* 2008]. As can be seen from Figure 11, the ratio of n-3/n-6 PUFA in milk fat of the monitored goats increased after moving from winter feeding to pasture and this trend was generally maintained until September with the only

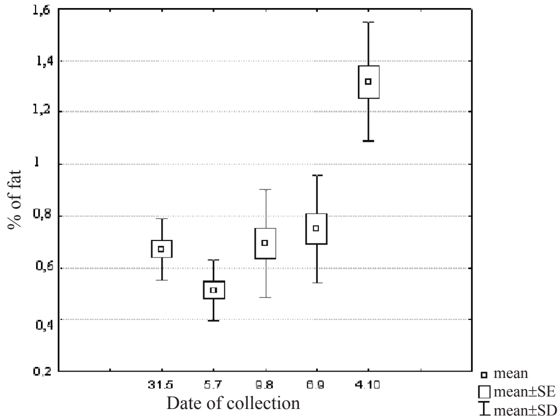

Fig. 10. Conjugated linoleic acid (CLA) content of goat milk fat on the day of sample collection.

Table 7. Results of Friedman ANOVA-test for conjugated linoleic acid (CLA) content of goat milk fat

Date of collection	Rank sum	Differences of rank sums (significant values are bolded)					Critical value of Friedman test (α=0.05)
		31.5.	5.7.	9.8.	6.9.	4.10.	
31.5.	36	0	18	1	5	**29**	
5.7.	18	18	0	17	**23**	**47**	
9.8.	35	1	17	0	6	**30**	22.0
6.9.	41	5	**23**	6	0	**24**	
4.10.	65	**29**	**47**	**30**	**24**	0	

Table 8. Results of Friedman ANOVA-test for the ratio of n-3/n-6 polyunsaturated fatty acids (PUFA) of goat milk fat

Date of collection	Rank sum	Differences of rank sums (significant values are bolded)					Critical value of Friedman test (α=0.05)
		31.5.	5.7.	9.8.	6.9.	4.10.	
31.5.	31	0	15	11	**28**	14	
5.7.	46	15	0	4	13	**29**	
9.8.	42	11	4	0	17	**25**	22.0
6.9.	59	**28**	13	17	0	**42**	
4.10.	17	14	**29**	**25**	**42**	0	

exception in August when the ratio slightly decreased. A marked decline was observed in October and this lowest value significantly differed from all other measurements besides the value for May (Tab. 8). The highest n-3/n-6 PUFA ratio recorded in September was significantly different from the ratios found in May and in October.

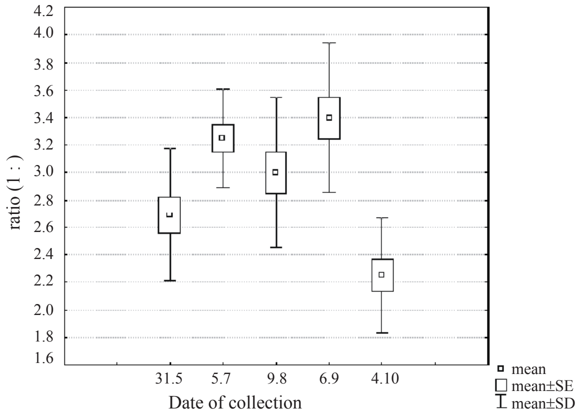

Fig. 11. Ratio of n-3/n-6 polyunsaturated fatty acids (PUFA) of goat milk fat on the day of sample collection.

Transfer of fatty acids from milk to cheese

Cheese produced from goat milk had very similar profile of fatty acids as milk. The significant differences in fatty acid content between milk fat and cheese fat occured only for PUFA (including CLA) in August (Tab. 9). In this month the content of PUFA in cheese fat was almost 0.6% lower than in milk fat (Fig. 12) but it probably resulted from the inoculation with the inappropriate starter cultures. Another factor influencing the differences could be the unstable conditions of cheese ripening. The obtained results are consistent with the relatively numerical studies indicating that fatty acid profiles of small ruminant cheeses are directly related to these of milk [Martin Alonso *et al.* 2000, Chilliard and Ferlay 2004, Ferlay *et al.* 2005, Pizzillo *et al.* 2005, Chilliard *et al.* 2006, Lucas *et al.* 2006, Raynal-Ljutovac *et al.* 2008]. Morand-Fehr *et al.* [2000] reported that the composition of goat milk and goat cheese reflected to some extent the composition of fat in the goat diet despite the processes of hydrogenation and isomerisation to which the fatty acids may be subjected in the rumen. Lucas *et al.* [2008], while characterising the composition of "Rocamadour", goat farm cheese, found that its fatty acid profile was more affected by the nature of the concentrates and the lactation stage of the herd than by the basic feed ration.

Table 9. Results of t-test for differences in fatty acid content between goat milk fat and cheese fat

Date of collection	Saturated fatty acids	Monounsaturated fatty acids	Polyunsaturated fatty acids	Conjugated linoleic acid
31.5	0.14	0.18	0.54	0.29
5.7	0.92	0.89	0.89	0.80
9.8	0.05	0.26	**0.01**	**0.01**
6.9	0.11	0.22	0.23	0.20

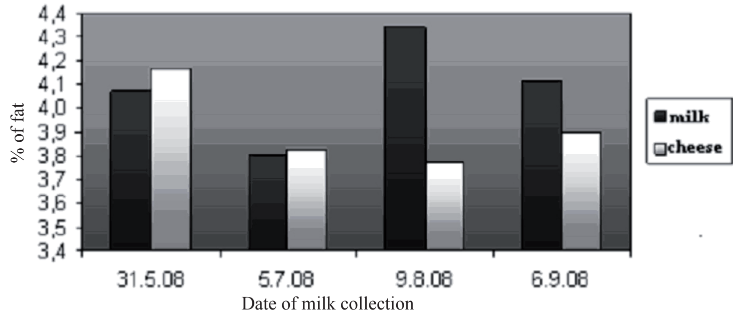

Fig. 12. Comparison of the content of polyunsaturated fatty acids (PUFA) of goat milk fat and cheese fat.

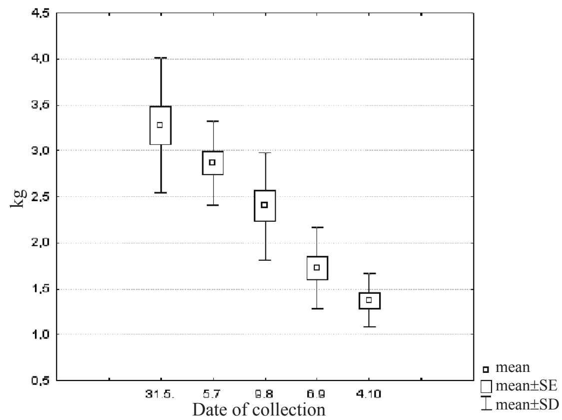

Fig. 13. Average goat milk yield on the day of sample collection.

Summarising, the botanical composition of the pasture, especially the proportion of herbs and clovers significantly influenced the feeding value and the content of protein and fat in forage dry matter which were the highest in July and October and the lowest in August. It was found that during grazing the content of SFA in goat milk fat continuously decreased. Opposite trend was recorded for MUFA. A significant increase of herb proportion in the total cover observed in autumn contributed to a highest content of PUFA (including CLA) in milk fat. However, this favourable increase of PUFA content at the end of grazing should also be related to the changes in milk fat composition during the progress of lactation.

The contents of fatty acids in goat milk fat and in farm goat natural cheese fat were generally similar which indicates that cheese-making process did not modify the fatty acid profile. Due to the confirmed transfer of fatty acids from goat milk to cheese a special attention should be paid to the quality of milk used in cheese-making. Thus, the high content of PUFA, including CLA, observed in milk of grazing goats provides a high content of these fatty acids in cheese made from this milk which guarantees fulfilling the requirements for functional foods.

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