IMPACT OF CONCENTRATE LEVEL AND STAGE OF LACTATION ON FATTY ACID COMPOSITION IN GOAT MILK*

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The impact of different amounts of concentrate and stage of lactation on fatty acid profile in milk fat was measured in 30 lactating Nubian goats. The ration included medium-quality hay, grazed pasture and concentrate feed (mashed barley, oats and beet pulp at 1:1:1 wet weight ratios). Half of the goats (group A) received 1.2 kg whereas group B received 1.0 kg of concentrate daily. Milk samples were taken 3 times during lactation. The total amounts of saturated fatty acids (SFA) increased gradually during lactation while polyunsaturated (PUFA) and monounsaturated fatty acids (MUFA) decreased. Group A had lower SFA but higher concentrations of MUFAs and PUFAs at all 3 samplings. Nubian goats fed more concentrate had FA ratios presumably more suitable for consumers of milk and milk products.

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INTRODUCTION

Because of the demand for goat milk, goat farming has expanded in recent years. Nubian goats are popular worldwide due to their high milk yield. Interest in goat milk and dairy products has increased due to published findings about their positive dietary and therapeutic effects on human health (Haenlein, 2004; Raynal-Ljutovac et al., 2008). Milk fat or fatty acids (FA) affect the physical and sensory characteristics of milk and milk products (Park et al., 2007; Gallier et al., 2012). Generally, FAs are grouped into saturated (SFA), monounsaturated (MUFA) and polyunsaturated FA with 2 or more double bonds (PUFA) and based on the configuration of double bonds into n-6 and n-3 fatty acids. Among the most important of n-6 PUFAs are linoleic acid and its products, such as γ-linolenic acid, dihomo-γ-linolenic acid and arachidonic acid. Similarly, α-linolenic acid is an important representative of n-3 PUFA the main metabolic products of which are eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) (Kremmyda et al., 2011; Stankova et al., 2013). The composition of FAs in milk of small ruminants varies, being influenced by the species and breed of animal, health, livestock rearing, parity and stage of lactation (SL) and diet intake and composition (Morand-Fehr et al., 2007; Stadnik et al., 2013). In this study, the effects of the supplemental concentrate level and the stage of lactation on Nubian goat milk FAs profile were determined.

MATERIAL AND METHODS

Biological sampling

Milk samples were collected from 30 Nubian goats bred in a farm in the Central Bohemian Region (Czech Republic). Selected goats balanced by age (2 years), date of kidding (March 2015), litter size (2 kids) and live body weight (65–75 kg) were divided into two groups (group A, $n = 15$ and group B, $n = 15$), each individually fed. The ration included medium-quality hay produced from the farm's own meadow stands (fibre

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Table 1. Fat content and the fatty acid composition (%) in the ration

	Hay	Grazed pasture	Concentrate feed
Fat content (%)	1.089	1.933	3.353
Fatty acids (%)			
Caproic (C6:0)	0.006	0.004	0.008
Caprylic (C8:0)	0.045	0.010	0.004
Capric (C10:0)	0.034	0.013	0.006
Palmitic (C16:0)	22.829	14.775	11.587
Oleic (C18:1)	21.624	6.348	23.380
Linoleic (C18:2)	17.935	15.424	58.307
γ-Linolenic (C18:3)	0.283	0.175	0.024
α-Linolenic (C18:3-9)	21.990	56.051	2.183
Arachidonic (C20:4)		0.012	0.003
EPA (C20:5)	0.552	0.343	0.123
DHA (C22:6)	0.101		0.018
SFA (%)	32.077	18.051	14.094
MUFA (%)	25.44	9.31	24.783
PUFA (%)	42.481	72.639	61.123
n-3 PUFA (%)	23.017	56.853	2.579
n- 6 PUFA (%)	19.316	15.786	58.518

EPA = eicosapentaenoic acid, DHA = docosahexaenoic acid, SFA = saturated fatty acid, MUFA = monounsaturated fatty acid, PUFA = polyunsaturated fatty acid

content 38%) *ad libitum*, with an average consumption of 1.5 kg per goat per day, grazed pasture (free choice) and concentrate feed. The pasture contained *Festuca pratensis*, *Festuca rubra*, *Lolium perenne*, *Poa pratensis* and *Trifolium repens* and during the vegetation period also *Taraxacum officinale*, *Lotus corniculatus*, *Achillea millefolium*, *Vicia cracca*, *Urtica dioica* and other plants. Concentrate feed (mashed barley, oats and beet pulp at 1:1:1 wet weight ratios) was offered individually during the morning milking (per A group head 1.2 kg (17% of diet supplement) and per B group head 1.0 kg (14% of diet supplement) daily). The fat content and the composition of fatty acids were determined in the ration (Table 1). Water and mineral licks were available free choice all year round. Goats were milked by hand twice daily, at 6:00 and 17:00 h. For evaluation, only milk from 1st milking was used (Carta et al., 2008). Milk samples (200 ml) were collected from each animal into sample tubes on days 60, 120 and 180 of lactation (April–October 2015) under sterile conditions, cooled down to 5–8°C, and transported in a thermo-box to the milk laboratory at the Czech University of Life Sciences Prague.

Determination of milk fatty acids

The total milk fat content was determined according to ČSN EN ISO 1211 (570534) (2011). Methanolysis was performed using the catalytic action of potassium hydroxide extracted in the form of methyl esters in heptane. Isolated methyl esters were determined by gas chromatography (Master GC, Dani split mode, FID detector, Italy) in a column with a stationary phase of polyethylene glycol (FameWax – 30 m × 0.32 mm × 0.25 mm). Helium was used as the carrier gas at a flow rate of 5 ml min^{-1}. The records were evaluated using Clarity 2nd, 5th and quantified based on retention times of known standard (Food Industry FAME Mix, Restek, USA).

The atherogenic index (AI) was calculated as AI = (C12:0 + 4 × C14:0 + C16:0)/(MUFA + PUFA) (Samkova et al. (2008) and the thrombogenic index (TI) as TI = (C14:0 + C16:0 + C18:0)/0.5 × MUFA + 0.5 × $PUFA_{(n-6)}$ + 3 × $PUFA_{(n-3)}$ + $PUFA_{(n-3/n-6))}$ (Ulbricht, Southgate, 1991).

Statistical analysis

The statistical analysis was performed using ANOVA of the SAS software (Version 9.3, 2011). General linear model with the fixed effects of concentrate supplement in diet (SD) and day of samples collection (DC) was adapted to explain the variability among dependent variables (FAs). Also the effect of the SD × DC interaction was tested during the ongoing analysis. However, it was non-significant for all the evaluated traits and therefore it was excluded from the model. To evaluate the impact of the independent variables on FAs proportion, the following equation was applied:

Table 2.Impact of diet and stage of lactation on FAs groups profile or their ratios

Parameters	Supplement in diet		Day of collection			Conclusiveness	
	1.2 kg	1.0 kg	60	120	180	SD	DC
	LSM	LSM	LSM	LSM	LSM	*P*-value	*P*-value
SFA	78.09	79.58	77.66[a]	77.95[a]	80.88[b]	0.08	0.01
MUFA	18.00	17.59	18.58[a]	18.72[a]	16.07[b]	0.60	0.01
PUFA	3.91[a]	2.83[b]	3.75[a]	3.33	3.04[b]	0.01	0.01
n-6 PUFA	2.89[a]	1.92[b]	2.88[a]	2.22[b]	2.12[b]	0.01	0.01
n-3 PUFA	0.95[a]	0.81[b]	0.80[a]	1.01[b]	0.82[a]	0.02	0.01
n-6/n-3	3.30[a]	2.41[b]	3.68[a]	2.25[b]	2.63[b]	0.01	0.01
SFA/MUFA	4.59	4.59	4.30[a]	4.28[a]	5.18[b]	0.99	0.01
SFA/PUFA	20.77[a]	29.02[b]	21.97[a]	24.95	27.77[b]	0.01	0.01
MUFA/PUFA	4.73a	6.33[b]	5.27	5.81	5.51	0.01	0.33
AI	3.94	4.25	3.55[a]	3.65[a]	5.08[b]	0.28	0.01
TI	3.62	3.97	3.48[a]	3.63[a]	4.28[b]	0.07	0.01

LSM =Least SquaresMeans,Conclusiveness= conclusiveness of evaluated factors and their interaction in model equation, DC =days of collection, SD = concentrate supplement in diet, SFA = saturated fatty acid, MUFA = monounsaturated fatty acid, PUFA = polyunsaturated fatty acid, AI = atherogenic index, TI = thrombogenic index

a, b different superscripts in rows mean a significant difference (P<0.05)

$Y_{ijk} = \mu + SD_i + DC_j + e_{ijk}$

where:

Y_{ijk} = value of the trait

μ = overall mean

SD_i = effect of concentrate supplement in diet (i = group A 1.2 kg of concentrate supplement in diet, n = 15; group B 1.0 kg of concentrate supplement in diet, n = 15)

DC_j = day of samples collection (j = 60th day of samples collection, n = 30; 120th day of samples collection, n = 30; 180th day of samples collection, n = 30)

e_{ijk} = residual error

The Tukey-Kramer method was applied for comparison and evaluating significant differences between Least Squares Means. Significance levels of $P < 0.05$ and $P < 0.01$ were used to evaluate the differences between groups.

RESULTS

The effect of SD was significant ($P < 0.01$) for total milk fat percentage. Higher percentages of milk fat were detected in group A (day 60 = 5.02%, day 120 = 4.52%, day 180 = 5.93%) than group B (day 60 = 4.25%, day 120 = 4.11%, day 180 = 4.35%). The effects of diet and stage of lactation on FAs groups profile, their ratios, AI and TI in goat milk are summarised in Table 2. The total amount of SFA tended to be higher in B group (+1.49%). Its percentage also increased gradually during ongoing lactation (from day 60 till day 180 of samples collection). A higher prevalence of MUFAs and PUFAs in group A and at days 60 and 120 of samples collection could be considered positive (Table 2). The profile as a percentage of selected FAs in Nubian goat milk is presented in Table 3.

DISCUSSION

In the present study, also the total fat content in Nubian goat milk was determined. The concentration of fat in the milk of small ruminants is affected by SL (Komprej et al., 2012). Physiological changes in mammary gland during lactation are responsible for the changes in milk FA content. Being dependent on SL, the total fat content cannot be considered independent variables (Guler et al., 2007; Toyes Vargas et al., 2014). During lactation the concentration of fat in Nubian goat milk increased from 4.0 to 4.8% (Soryal et al., 2005). According to Gonzalo et al. (1994), milk fat concentration increased from the 9th week until the end of lactation while Sanz Sampelayo et al. (2007) reported on low milk fat content at the beginning of lactation, which gradually increased. This is consistent with the results of the present experiment. The aim of our study was to evaluate the profile of FAs in Nubian goat milk. In Alpine and Nubian goat milk in the US production systems, SFA normally contain approximately 20% of total fatty acids (Soryal et al., 2005). In our study, the SFA content was almost

Table 3.Fatty acid composition (%) in milk of Nubian goats

Fatty acid	Supplement in diet		Day of collection			Conclusiveness	
LSM	1.2 kg LSM	1.0 kg LSM	60 LSM	120 LSM	180 LSM	SD *P*-value	DC *P*-value
Butyric (C4:0)	1.90	1.53	2.13[a]	1.50[b]	1.51[b]	0.14	0.06
Caproic (C6:0)	3.14	3.02	3.64[a]	2.91[b]	2.70[b]	0.62	0.01
Caprylic (C8:0)	3.96	3.92	4.54[a]	3.78[b]	3.49[b]	0.85	0.01
Capric (C10:0)	12.95	12.91	13.20	12.37	13.21	0.92	0.18
Palmitic (C16:0)	26.65	26.84	24.26[a]	26.60[b]	29.39[c]	0.81	0.01
Oleic (C18:1)	16.26	16.08	17.06[a]	17.35[a]	14.09[b]	0.82	0.01
Linoleic (C18:2)	2.69[a]	1.80[b]	2.71[a]	2.05[b]	1.97[b]	0.01	0.01
γ-Linolenic (C18:3)	0.01	0.01	0.01	0.01	0.01	0.06	0.29
α-Linolenic (C18:3-9)	0.88[a]	0.74[b]	0.75[a]	0.92[b]	0.76[a]	0.02	0.02
Arachidonic (C20:4)	0.19[a]	0.12[b]	0.16	0.16	0.15	0.01	0.78
EPA (C20:5)	0.01	0.01	0.008[a]	0.010[a]	0.002[b]	0.17	0.02
DHA (C22:6)	0.06	0.06	0.04[a]	0.08[b]	0.07[b]	0.25	0.01

LSM =Least SquaresMeans,Conclusiveness= conclusiveness of evaluated factors and their interaction in model equation, DC =days of collection, SD = concentrate supplement in diet, EPA =eicosapentaenoicacid, DHA =docosahexaenoicacid

[a–c] different superscripts in rows mean a significant difference (P<0.05)

4 times higher than the level for both groups and during the whole time of samples collection. This could be due to the feed supply or concentrate (Stadnik et al., 2013). Generally, a higher SFA percentage in milk is less healthful for consumers (Baumann, Lock, 2010). In this study, SFAs percentages were lower for goats fed more concentrate. However, changes in the percentages of individual SFAs during lactation were minimal when compared to the results of Guler et al. (2007) studying milk characteristics of Damascus goats and the German fawn and Hair goat crossbreds under Turkish conditions. Unsaturated fatty acids (MUFA and PUFA) presumably have positive effects on human health due to delivery of biologically active substances important for metabolism (Komprej et al., 2012). The factor of SD was non-significant for MUFA, SFA/MUFA, AI and slightly non-significant for SFA and TI traits. On the other hand, days of samples collection (DC) were mainly significant in the model, except for the MUFA/PUFA percentage. The total amount of SFAs was higher in B group. As expected, an opposite tendency was detected in PUFA and MUFA percentages. Significantly the lowest n-3 and n-6 PUFAs, as well as their ratio, were observed in group B (with a lower concentrate supplement). A higher PUFA (especially n-3 and n-6) content in goat milk has a potential for improving consumers' health (Toral et al., 2012). The FAs groups also showed practically no tendency during the experimental period, despite significant differences in milk FAs content at particular sampling days. The AI and TI parameters of goat milk represent beneficial indicators for human health (Poti et al., 2015). The highest AI values were found in goats with a lower concentrate supplement in the.diet (group B); however, non-significantly. A significant increase of AI with advancing days of samples collection (P < 0.05) was also detected. In the study of Poti et al. (2015), AI was proved to be significantly lower in experimental treatments with micro-algae compared to control ones. A similar tendency was observed in TI values. This positive impact of a higher concentrate intake was confirmed by AI and TI values in which lower values predicted a decreased risk of atherogenic and thrombogenic diseases. Both of these indexes were also affected by SL; the lowest values were detected at sampling day 60 and then the values were increasing.

The profile as a percentage of selected FAs in Nubian goat milk is presented in Table 3. SD was not significant in most fatty acids but for linoleic, α-linolenic and arachidonic acids. On the other hand, DC was not significant only for butyric, capric, γ-linolenic and arachidonic acids. All the other FAs evaluated were significant in the model. The FAs percentages did not significantly differ concerning SD, except for linoleic, α-linolenic and arachidonic acids. Their higher percentages (+0.89% of linoleic, +0.14% of α-linolenic and +0.07% of arachidonic acid) were detected in higher SD (1.2 kg). Significantly the highest percentage of butyric, caproic, caprylic oleic and linoleic FAs was detected during the 1st samples collection (day 60 of lactation). Generally, the lowest values were observed in the 3rd samples collection (day 180 of lactation). An opposite tendency was observed in palmitic FA, which significantly increased with samples collection days (from 24.26% on day 60 to 29.39% on day 180).

CONCLUSION

The present results indicate that a relatively small difference in the amount of supplemental concentrates (e.g. 200 g per head daily) could change the representation of FAs and thus improve the value of goat milk as a primary food for further processing. The decrease in unsaturated FAs in milk during lactation appears to be a physiologically natural state. The results of the present study should be useful and informative for milk consumers, producers and scientists.

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