POLISH JOURNAL OF FOOD AND NUTRITION SCIENCES
Pol. J. Food Nutr. Sci. 2006, Vol. 15/56, SI 1, pp. 51–55

EFFECT OF THE FEEDING PERIOD ON THE CHEMICAL COMPOSITION AND FATTY ACID PROFILE OF MILK FROM FRENCH ALPINE DAIRY GOATS

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Key words: goat's milk, chemical composition, fatty acids.

The chemical composition and fatty acid profile of milk from French Alpine dairy goats, obtained during the period of summer feeding and winter feeding, were studied. Milk samples were collected at one-month intervals, to determine dry matter, solids non-fat, protein, fat, fatty acid profile, lactose, urea and somatic cell count. The fatty acid composition of milk fat was determined for particular experimental twice during lactation, *i.e.* in the middle of the winter season and in the middle of the summer season.

It was found that goat's milk produced in winter had higher levels of dry matter, fat, protein and urea, and a lower lactose content. Goat's milk obtained over this feeding period had a higher urea content. The somatic cell count recorded in milk from the experimental goats remained within the physiological norms for goat's milk.

The feeding period had a significant effect on the fatty acid profile of goat's milk. Milk produced in summer had higher levels of unsaturated fatty acids, especially polyunsaturated fatty acids, as well as a more favorable ratio between unsaturated fatty acids and saturated fatty acids, and a lower ratio between monounsaturated fatty acids and polyunsaturated fatty acids. Goat's milk obtained over this period had higher concentrations of linoleic acid ($C_{18:2}$), linolenic acid ($C_{18:3}$) and conjugated dienes of linoleic acid.

INTRODUCTION

The main goal of goat management in Poland is milk production. The amount of milk produced and its chemical composition are dependent upon a variety of factors, among which the key role is played by the diet [Kowalski, 1997]. The chemical composition of goat's milk varies with breed and feeding. The most significant fluctuations are observed in fat concentration, whereas the levels of lactose and protein remain more or less stable. Goat's milk contains more whey proteins, like albumins and globulins (25–39% total protein), compared with cow's milk (15–17%). In addition, goat's milk protein contains small amounts of alpha s1-casein, which makes it more suitable for children with cow's milk protein allergy [Bielak, 1993].

Faster and more thorough digestion of goat's milk fat results primarily from a different physical structure of fat globules, characterised by smaller diameters and better emulsification [Kostyra *et al.*, 1996a]. Goat's milk fat has much higher concentrations of short- and medium-chain fatty acids, in comparison with cow's milk. Easier goat's milk digestion is also related to the low level of oleic acid ($C_{18:1}$) [Bielak, 1993].

The nutritional value of fat is considerably affected by the fatty acid profile. Particular attention should be paid to the concentrations and proportions of saturated fatty acids and unsaturated fatty acids), as well as the ratio between monounsaturated fatty acids and polyunsaturated fatty acids. Conjugated dienes of linoleic acid are the best known group of bioactive components of the lipid fraction in milk They are formed by symbiotic bacteria (butyrivibrio fibrisolvens) as a result of enzymatic reactions. These bacteria produce an enzyme indispensable for synthesis of conjugated dienes of linoleic acid in the rumen, in the amounts indicating biological activity. It was found that conjugated linoleic acid, present mainly in fat of ruminants, inhibits the development of neoplastic diseases in animals and is a strong antiarteriosclerotic agent [Patkowska-Sokoła *et al.*, 2000; Reklewska *et al.*, 2003]. A new diagnostic parameter that arouses a growing interest among researchers and producers is the urea content of milk. A high urea content of goat's milk may reduce productivity and reproductive performance, as well as increase the somatic cell count [Osten-Sacken, 1999]. The fatty acid profile of goat's milk is also studied on a wider and wider scale nowadays [Patkowska-Sokoła *et al.*, 2000].

The aim of the present study was to determine the effect of the feeding period on the chemical composition and fatty acid profile of milk from French Alpine dairy goats.

MATERIAL AND METHODS

The study was performed in 2004 on the farm "Nad Arem" in Kierźliny near Barczewo. The experimental mate-

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rials comprised milk samples collected individually from 20 French Alpine dairy goats during winter and summer feeding periods. The goats of group I (winter feeding; October–April) were fed meadow hay, wheat bran, ground grain, oat straw and polfamix "K". The goats of group II (summer feeding; May–September) were fed green forage, meadow hay and polfamix "K". The feeding levels were consistent with the relevant standards, established by the Institute of Animal Husbandry [Feeding Standards, 1998].

The goats were milked once daily. Control milking was conducted once a month. Fat, protein, lactose, dry matter, solids non-fat, urea and somatic cell count were determined in milk samples with the CombiFoss 6200 apparatus, at the Milk Testing Laboratory, National Center for Animal Breeding, Inspectorate in Olsztyn.

The fatty acid composition of milk fat was determined for particular experimental twice during lactation, *i.e.* in the middle of the winter season and in the middle of the summer season. Fat was extracted from milk samples by the Roese-Gottlieb method. The composition of fatty acids was determined by esterification [Peisker, 1964] followed by gas chromatography, using a PYE Unicam chromatograph, series 104, with flame-ionization detection, a glass column 2.1 m in length and 4 mm in inner diameter [Żegarska *et al.*, 1979]. The analysis was performed at the Department of Instrumental Analysis, Faculty of Food Sciences, University of Warmia and Mazury in Olsztyn.

The results were verified statistically by an analysis of variance in a one-factor orthogonal design, taking into account two feeding periods in the mathematical model. The fatty acid profile (20 samples – group I and 20 samples – group II) was determined by the t-test.

RESULTS AND DISCUSSION

Table 1 presents the chemical composition of goat's milk, taking into consideration the feeding period. Milk produced over the winter months (group I) contained significantly more dry matter, fat and protein, and significantly less lactose. Higher concentrations of major components in goat's milk obtained during winter feeding indicate that the kind of feed had a profound influence on its composition.

The levels of fat and protein in milk from the group I goats were higher than the minimal requirements of the Polish Standard [1994] concerning pasteurised goat's milk. Milk from the group II goats contained more protein and less fat than the minimal limits specified in the Polish Standard. In terms of the content of solids non-fat, milk from goats of both groups fulfilled the requirements of this Polish Standard.

Similar results were obtained by Borys *et al.* [2000]. In their experiment sheep's milk produced in winter contained significantly more dry matter, protein and fat, and less lactose than milk produced over the summer months. On the other hand, Szymanowska *et al.* [2002] found that milk from Saanen dairy goats obtained over the summer feeding period had a higher fat content than milk obtained over the winter feeding period.

The urea content of goat's milk produced in winter (Table 1) was significantly higher (by 69.05 mg/L), compared with milk obtained in summer (385.28 mg/L). According to Kostyra *et al.* [1996b], the optimum urea level in goat's milk is 360 to 420 mg/L. A too high urea content may reduce productivity, cause reproduction problems and an increase in the somatic cell count in milk [Osten-Sacken, 1999]. The elevated urea level observed in milk from the goats of group I could contribute to the increased somatic cell count. Moreover, it should be stressed that the urea level in goat's milk is significantly correlated with casein stability [Wagner *et al.*, 1994]. The somatic cell count recorded in milk from the experimental goats (Table 1) remained within the physiological norms for goat's milk [Tetze *et al.*, 1999].

TABLE 1. Chemical composition and somatic cell count in milk from French Alpine dairy goats.

Chemical composition and somatic cell count	Statistical measures	Groups I (winter feeding)	Groups II (summer feeding)
Fat (%)	$\bar{x}$	3.59^{a}	3.39^{b}
	s	0.80	0.69
	v	22.28	20.35
Protein (%)	$\bar{x}$	3.85^{a}	3.41^{b}
	s	0.68	0.49
	v	17.66	14.37
Lactose (%)	$\bar{x}$	4.43^{B}	4.76^{A}
	s	0.22	0.22
	v	4.97	4.62
Dry matter (%)	$\bar{x}$	13.06^{A}	12.09^{B}
	s	1.33	1.16
	v	10.78	9.59
Solids non-fat (%)	$\bar{x}$	8.99	8.70
	s	0.62	0.56
	v	6.90	6.44
Somatic cell count (10^3/mL)	$\bar{x}$	968.73	886.00
	s	319.44	283.47
	v	33.98	31.99
Urea (mg/L)	$\bar{x}$	454.33^{a}	385.28^{b}
	s	98.66	86.27
	v	21.72	22.39

A, B – $p \leq 0.001$; a, b – $p \leq 0.005$

The fatty acid profile of goat's milk and its changes resulting from the feeding period are shown in Table 2. An analysis of the results indicated that the concentrations of volatile fatty acids were similar in both groups. Milk produced during winter feeding contained more saturated fatty acids than milk produced during summer feeding. As regards particular fatty acids of this group, it was found that goat's milk obtained over summer contained higher concentrations of such acids as $C_{15:0}$, $C_{17:0}$ (significant differences) and a lower percentage of $C_{16:0}$, in comparison with milk obtained over winter. However, this had no significant effect on the total pool of saturated acids in milk from goats of the two groups. Different results were obtained by Szymanowska *et al.* [2002], who demonstrated that in summer milk from Saanen dairy goats and Polish White Improved dairy goats contained more palmitic acid C16:0.

Milk produced during the summer feeding period had

higher levels of total UFA and lower levels of MUFA, despite significant differences between the groups in the concentrations of such acids as $C_{12:1}$, $C_{14:1}$, $C_{18:1}$. Szymanowska *et al.* [2002] observed a similar tendency in the $C_{18:1}$ content of milk from Saanen dairy goats produced over the winter months.

The concentrations of PUFA in goat's milk were significantly higher (Table 2) in summer than in winter. The levels of $C_{18:2}$, $C_{18:3}$ and conjugated linoleic acid in goat's milk were also statistically significantly higher during summer feeding. Szymanowska *et al.* [2002] obtained different results. These authors recorded lower concentrations of $C_{18:2}$ and $C_{18:3}$ in milk from Polish White Improved dairy goats in the summer.

The wide range of fluctuations in the conjugated linoleic acid content of fat of ruminants (2–30 mg/g) is related, among others, to feeding conditions. It follows that the diet can be balanced so as to achieve the optimum concentration of this acid. Feed components rich in polyunsaturated fatty acids (rapeseed meal, sunflower meal, linseed meal) positively affect the conjugated linoleic acid content [Baldi *et al.*, 1992; Kelly *et al.*, 1998; Reklewska *et al.*, 2003].

The UFA/SFA, MUFA/PUFA and DFA/OFA ratios are presented in Table 2. The relation between UFA and SFA is of primary importance to consumers. Their ratio of 2:1 is considered to be optimal [Patkowska-Sokoła *et al.*, 2000]. In our study goat's milk produced during the summer feeding period was characterized by a more favorable UFA to SFA ratio. Milk from the goats of group II had a lower ratio between MUFA and PUFA. Similar results were reported by Kelly *et al.* [1998], Borys *et al.* [2000] and Reklewska *et al.* [2003] for cow's milk.

In the present experiment we compared the levels of hypo- and hypercholesterolemic acids (DFA=UFA=$C_{18:0}$ and OFA=SFA–$C_{18:0}$) and their ratio in goat's milk of two groups (Table 2). Milk from the group I goats contained less DFA than milk from the group II goats.

Borys *et al.* [2000], who studied the fatty acid profile of sheep's milk, demonstrated that summer feeding had a beneficial effect on the percentages of functional fatty acids. Similar results were obtained by Kelly *et al.* [1998], who proved that pasture feeding positively affected an increase in the levels of polyunsaturated fatty acids in cow's milk, especially conjugated linoleic acid.

TABLE 2. Fatty acid composition of goat's milk.

Fatty acids (%)	Group					
	I (winter feeding)			II (summer feeding)		
	$\bar{x}$	s	v	$\bar{x}$	s	V
$C_{4:0}$	1.57	0.37	23.57	1.74	0.35	20.11
$C_{6:0}$	1.84	0.32	17.39	2.01	0.24	11.94
$C_{8:0}$	2.10	0.36	17.14	2.35	0.31	13.19
$C_{10:0}$	7.61	1.00	13.14	8.57	1.36	15.87
Total volatile fatty acids	13.12	1.88	14.33	14.67	1.93	13.16
$C_{12:0}$	3.69	0.46	11.16	3.84	0.66	17.19
$C_{13:0}$	0.10	0.01	10.00	0.11	0.02	18.18
$C_{14:0}$	11.56	1.12	9.69	10.82	1.16	10.72
C_{14izo}	0.10	0.02	20.00	0.09	0.05	55.56
$C_{15:0}$	1.08^{B}	0.14	12.96	1.43^{A}	0.25	17.48
C_{16izo}	0.37	0.09	24.32	0.27	0.08	29.63
$C_{16:0}$	31.75^{A}	2.63	8.28	28.15^{B}	1.47	5.22
$C_{17:0}$	0.58^{B}	0.09	15.51	0.77^{A}	0.08	10.39
$C_{18:0}$	9.98	2.24	22.44	11.18	1.89	16.91
Total saturated fatty acids (SFA)	59.21	2.84	4.80	56.67	2.51	4.43
$C_{10:1}$	0.21	0.06	28.57	0.16	0.05	31.25
$C_{12:1}$	0.09a	0.06	66.67	0.02b	0.05	250.00
$C_{14:1}$	0.23^{A}	0.06	26.09	0.14^{B}	0.04	28.57
$C_{16:1}$	0.72	0.35	48.61	0.62	0.15	24.19
$C_{17:1}$	0.33	0.09	27.27	0.37	0.09	24.32
$C_{18:1}$	24.02	3.25	13.53	23.35	3.26	13.96
Total monounsaturated fatty acids (MUFA)	25.60	3.42	13.36	24.66	3.36	13.63
$C_{18:2}$	1.61^{B}	0.09	5.60	2.20^{A}	0.27	12.27
$C_{18:3}$	0.17^{B}	0.08	47.06	0.87^{A}	0.24	27.59
$C_{18:2}$ conjugated	0.29^{B}	0.06	20.69	0.94^{A}	0.34	36.17
Total polyunsaturated fatty acids (PUFA)	2.07^{B}	0.18	8.97	4.01^{A}	0.76	18.95
Total unsaturated fatty acids (UFA)	27.67	3.41	12.32	28.67	3.98	13.88
UFA : SFA	0.38	0.06	15.79	0.41	0.08	19.51
MUFA : PUFA	12.45^{B}	2.02	16.22	6.24^{A}	0.82	13.14
DFA = UFA + C18:0	37.65	3.90	10.36	39.85	3.90	9.79
OFA = SFA − C18:0	62.35	4.44	7.12	60.15	4.44	7.38
DFA : OFA	0.61	0.10	16.39	0.67	0.13	19.40

DFA – hypocholesterolemic fatty acid; OFA – hypercholesterolemic fatty acids; A,B – $p \leq 0.001$; a, b – $p \leq 0.005$

CONCLUSIONS

1. Goat's milk produced in winter had higher levels of dry matter, fat and protein, and a lower lactose content.

2. Goat's milk obtained during winter feeding had a higher urea content. The somatic cell count recorded in milk from the experimental goats remained within the physiological norms for goat's milk.

3. Milk fat obtained in summer had higher percentages of unsaturated fatty acids, especially polyunsaturated fatty acids.

4. Goats' milk produced during the summer feeding had a more favorable ratio between unsaturated fatty acids and saturated fatty acids, and a lower ratio between monounsaturated fatty acids and polyunsaturated fatty acids.

5. Goat's milk obtained in summer was characterised by a higher concentration of hypocholesterolemic fatty acids.

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WPŁYW SEZONU ŻYWIENIA NA SKŁAD CHEMICZNY I PROFIL KWASÓW TŁUSZCZOWYCH W MLEKU KÓZ RASY ALPEJSKIEJ FRANCUSKIEJ

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Badano skład chemiczny i profil kwasów tłuszczowych w mleku kóz rasy alpejskiej francuskiej pochodzącym z okresu żywienia zimowego i letniego. W próbkach mleka pobieranych w odstępach miesięcznych oznaczono zawartość: suchej masy, suchej masy beztłuszczowej, białka, tłuszczu, laktozy, mocznika i komórek somatycznych. Skład kwasów tłuszczowych tłuszczu mleka koziego dla poszczególnych kóz doświadczalnych ustalono dwukrotnie w okresie laktacji, tj. w połowie sezonu żywienia zimowego i żywienia letniego.

Badania wykazały, że mleko kozie pozyskiwane w okresie żywienia zimowego charakteryzowało się wyższą zawartością suchej masy, tłuszczu i białka, a niższą zawartością laktozy. W mleku kóz z tego okresu żywienia wykazano wyższą zawartość mocznika. Liczba komórek somatycznych stwierdzona w mleku badanych grup kóz mieści się w granicach norm fizjologicznych, przyjętych dla mleka koziego.

Badania wykazały wpływ sezonu żywienia na profil kwasów tłuszczowych mleka. Mleko kozie pochodzące z okresu żywienia letniego charakteryzuje się wyższym udziałem kwasów nienasyconych, a szczególnie wielonienasyconych. Mleko z tego okresu żywienia kóz odznaczało się korzystniejszym stosunkiem kwasów UFA do SFA, a także niższym stosunkiem kwasów MUFA do PUFA. W mleku z sezonu żywienia letniego stwierdzono wyższą zawartość kwasów: linolowego ($C_{18:2}$), linoleinowego ($C_{18:3}$) i sprzężonego dienu kwasu linolowego (SKL).