Animal Science Papers and Reports vol. 28 (2010) no. 4, 389-395
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The concentration of free fatty acids in goat milk as related to the stage of lactation, age and somatic cell count*

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(Received May 8, 2010; accepted September 30, 2010)

The study aimed at determining the concentration of free fatty acids (FFA) and some chemical and physical traits of goat milk as related to the stage of lactation, age and somatic cell count (SCC). Used were 60 Polish White Improved goats. Diets were formulated according to the INRA standards and met all the individual nutritive requirements of goats. Milk samples were taken every month throughout the whole lactation. The highest level of FFA and fat content of milk was recorded in the last stage of lactation, in primiparous does and in milk with lowest SCC. However, in general, because the goats were free from sub- and clinical *mastitis* their milk was characterized by low level of FFA (<1.0 mEq/L), Thus, milk obtained from goats with healthy mammary glands was characterized by low susceptibility to lipolysis.

KEY WORDS: free fatty acids /goat / lactation / milk / somatic cell count

Milk is an important source of protein and fat in human diet. The chemical composition and nutritive value of milk is affected by various factors [Strzałkowska *et*

*Research was realised within the project "BIOFOOD" – innovative, functional products of animal origin no. POIG.01.01.02-014-090/09 co-financed by the European Union from the European Regional Development Fund within the Innovative Economy Operational Programme 2007-2013 and Research Project of IGAB PAS No. S.V.3
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al. 2009, Jóźwik *et al.* 2010]. Among others, free fatty acids (FFA) content negatively influence the palatability (taste, aroma) of fresh milk. It is especially important with reference to goat milk and its products. Under unfavourable conditions goat milk is subjected to lipolysis in which the FFA are produced. Such changes prejudice the technological value of milk as a raw material for the dairy industry and in consequence lower the yield of the products obtained [Morgan and Gaborit 2001, Chilliard *et al*. 2003, Atasoy and Türkođlu 2009].

The lipolysis of goat milk fat is a complex process affected by numerous factors, both genetic and environmental. The genetic factors are: the structure and size of fat globules, as well as fatty acids structure and profile of the milk fat. Fat globules in goat milk are characterized by a smaller diameter than those of cow milk and are naturally emulated [Andrade and Schmidely 2006, Park *et al.* 2007, D'Urso *et al*. 2008, Tsiplakou and Zervas 2008, Rodriguez-Alcala *et al*. 2009, Silanikove *et al*. 2010]. Due to such properties, goat milk fat is digested quicker and easier compared to cow milk fat, but is also more susceptible to lipolysis. Moreover, the group of FA dominant in the goat milk are short- or medium-chain, more susceptible to lipolysis than long-chain acids [Matsushita *et al*. 2007, Pandya and Ghodke 2007, Strzałkowska *et al*. 2009]. The main environmental factors affecting the intensity and progress of lipolysis are: stage of lactation, health condition of the mammary gland, nutrition, health condition of the animal in general and milking method [Aganga *et al.* 2002, Collins *et al*. 2003, Fekadu *et al*. 2005]. Facing the above the study was undertaken aiming at determining the relationship between the stage of lactation, goat age and somatic cell count of milk and milk concentration of FFA and its physico-chemical traits.

Material and methods

Animals

The study was carried out on 60 Polish White Improved goats from the flock maintained at the Experimental Farm of the Institute of Genetics and Animal Breeding, Jastrzębiec, Poland. The mean yield in the flock was about 800 kg milk per 260 days of lactation, containing 3.3% fat and 3.0% protein. The goats were in lactation I to VI. Diets fed were formulated according to the Institute National de la Recherche Agronomique standards adjusted by the National Research Institute of Animal Production [INRA, 2001], which met all their individual nutritive requirements. The winter diet (October to May) consisted of corn silage, hay, carrot and concentrate, fed according to milk yield together with a mineral and vitamin premix, chalk and NaCl. During the summer season (June to September) instead of hay and carrot the fresh grass was offered. All animals were daily examined for clinical *mastitis*. During the study the clinical symptoms of *mastitis* did not occur.

Sampling milk

The goats were machine-milked twice a day according to standard procedures. Prior to milking, the teats were washed with clean tap water and dried with a single service paper towel. Before attaching the milking machine to the teats, the first three to four streams of milk from both teats of each goat were discarded onto a strip cup and examined for any sign of *mastitis*. Morning and evening milk samples were mixed and passed for analyses. Milk samples were taken every month during the whole lactation, from February 2009 to November 2009. Altogether 536 milk samples were analysed.

Analytical

Milk was analysed by the Milk Laboratory of the Institute of Genetics and Animal Breeding, Jastrzębiec. The somatic cell count (SCC) was determined using the Bactocount IBC_M (Bentley, USA). Each milk sample was also analysed for free fatty acids, fat, protein, total solids, lactose, citric acid and acidity. The composition and parameters of milk were estimated using the MilkoScan FT2 device (Foss Electric, Hillerod, Denmark).

Statistical

Depending on the somatic cell count milk samples were divided into three groups: less than 4×10^5 (group I), from 4×10^5 to 1×10^6 (group II) and from 1×10^6 to 2×10^6 (group III) cells/ml. Three following stages of lactation were also distinguished: stage 1 – day 6 to 60, stage 2 – day 61 to 120 and stage 3 – from day 121 to the end of lactation, and three classes (parities) of lactation: lactation I, lactation II and lactation III (third to sixth).

Statistical evaluation of results was conducted on the basis of the GLM procedure of SAS Version 9.1 for Windows [SAS, SAS/STAT 2002-2003] using a model including the fixed effects of a SCC level, stage of lactation and parity. Except for the milk yield, a fixed regression on milk yield was used. The data for SCC were, prior to the statistical analysis, transformed to a logarithmic value (ln). The Pearson's correlations were estimated using the CORR procedure (SAS, SAS/STAT 2002-2003).

All procedures involving animals were in accordance with the Guiding Principals for the Care and Use of Research Animals and were approved by the Local Ethics Commission (Warsaw University of Life Sciences, Permission No. 56/2009).

Results and discussion

The changes in the FFA concentration and some physical-chemical traits of goat milk throughout the lactation are shown in Table 1. As expected, the daily milk yield and lactose content decreased with the progress of lactation. This was accompanied by an increase in the concentration of FFA and basic components – protein, casein and fat at the end of lactation. Similar results were obtained by Collins *et al*. [2003] and more recently by Kondyli *et al*. [2007]. In the present study the content of FFA of milk

was comparatively low throughout the whole lactation. Eknes *et al*.[2009] showed that when the FFA level of milk exceeds 2.0 mmol/l, the characteristic „goat" aroma gets stronger and milk may be unacceptable for some consumers. In the present study there was no increase in the level of FFA during the peak of lactation (Tab. 1), when the goats show a negative energy balance and, in particular the high yielding ones, intensively use up the fat reserves stored during the dry period. The studies conducted by Eknes *et al*. [2006] demonstrated that if goats, during the peak of lactation, use 30-40% of their fat reserves, it has a negative effect on the palatability of the milk yielded, because during this period the milk fat is synthesised from fatty acids obtained from hydrolysis of the fat tissue. The unfavourable changes in milk taste and flavour are caused during this period by high concentration of FFAs, in particular of a short chain (C6-C9). Chilliard *et al*. [2003] observed a significant positive correlation between milk fat lipolysis during the peak of lactation and the activity of lipoprotein lipase (LPL).

Table 1. Least squares means (LSM) and their standard errors (SE) for daily milk yield, milk chemical composition and milk physical traits across the three stages of lactation

Item	Stage I		Stage II		Stage III	
	LSM	SE	LSM	SE	LSM	SE
Daily milk yield (kg)	2.62^{A}	0.08	2.21^{B}	0.09	1.26^{C}	0.08
Fat (%)	3.59^{Aa}	0.07	3.25^{B}	0.06	3.74^{Ab}	0.07
FFA* (mEq/L)	0.79^{A}	0.03	0.77^{A}	0.02	0.90^{B}	0.02
Protein (%)	3.12^{A}	0.04	3.08^{A}	0.03	3.41^{B}	0.03
Casein (%)	2.58^{A}	0.03	2.39^{B}	0.02	2.85^{C}	0.03
Total solids (%)	12.44^{A}	0.09	11.54^{B}	0.08	12.54^{A}	0.09
Lactose (%)	4.62^{A}	0.01	4.52^{B}	0.02	4.42^{C}	0.02
Citric acid (%)	0.11^{A}	0.003	0.08^{B}	0.002	0.06^{C}	0.003
Acidity (SH)	5.44^{A}	0.11	5.48^{A}	0.10	7.36^{B}	0.08

$^{aA,\ldots}$Within rows means bearing different superscripts differ significantly at: small letters – P≤0.05; capitals – P≤0.01.
*FFA – free fatty acids.

Changes in the milk acidity during subsequent stages of lactation were related principally to changes in the content of the basic milk components, *i.e*., fat and total protein. (Tab. 1).

The highest daily milk yield, as well as content of fat, total protein and caseins of milk were observed during lactation I (Tab. 2). However, the milk of primiparous does was characterized also by a FFA concentration significantly higher than that observed in the milk in lactation II and lactations III to VI. The highest milk yield, observed in the group of primiparous does, together with the highest synthesis of milk components, could decide about the higher susceptibility to lipolysis of the milk fat of this group of goats. Similar results were obtained also in studies on cows: milk obtained from animals characterized by the highest daily milk yield was the most susceptible to the process of fat lipolysis (Strzałkowska *et al*. 2010 – unpublished data).

Table 2. Least squares means (LSM) and their standard errors (SE) for daily milk yield, milk chemical composition and milk physical traits across the number of lactation

Item	Lactation I		Lactation II		Lactation III-VI	
	LSM	SE	LSM	SE	LSM	SE
Daily milk yield (kg)	2.54^{a}	0.32	1.89^{a}	0.11	1.66^{b}	0.09
Fat (%)	3.63^{a}	0.27	3.48^{a}	0.09	3.27^{b}	0.08
FFA* (mEq/L)	0.98^{a}	0.11	0.78^{b}	0.04	0.70^{b}	0.03
Protein (%)	3.50^{a}	0.15	3.18^{b}	0.05	3.16^{b}	0.04
Casein (%)	2.78^{a}	0.12	2.53^{b}	0.04	2.51^{b}	0.03
Total solids (%)	12.57	0.36	12.11	0.13	11.84	0.10
Lactose (%)	4.52^{AB}	0.07	4.55^{A}	0.03	4.48^{B}	0.02
Citric acid (%)	0.07	0.012	0.09	0.004	0.09	0.003
Acidity (SH)	5.76	0.44	6.24	0.16	6.24	0.13

$^{aA,...}$Within rows means bearing different superscripts differ significantly at: small letters – P≤0.05; capitals – P≤0.01.
*FFA – free fatty acids.

In the present study, together with the increase of SCC, a decrease of the daily milk yield occurred (Tab. 3). The lowest daily milk yield (1.86 kg) was related to the highest SCC (from 1×10^{6} to 2×10^{6} cells/ml). Similar results were obtained by Zeng *et al.* [1997] and Raynal-Ljutovac *et al.* [2005]. The SCC had no impact on fat content of milk (Tab. 3). All SCC groups were characterized by a low FFA concentration (<1.0 mEq/l), but differences between groups occurred (P≤0.05). The highest values both of the milk yield and FFA concentration were recorded for group I with the lowest SCC ($<4\times10^{5}$) – Table 3. These results are contrary to those reported by Bachman *et al.* [1988], who observed a positive correlation between the SCC and FFA concentration

Table 3. Last squares means (LSM) and their standard errors (SE) for daily milk yield, milk chemical composition and milk physical traits according to level of somatic cells

Item	Group I		Group II		Group III	
	LSM	SE	LSM	SE	LSM	SE
Daily milk yield (kg)	2.22^{A}	0.07	2.01^{Ba}	0.08	1.86^{Bb}	0.08
Fat (%)	3.49	0.06	3.40	0.07	3.50	0.07
FFA* (mEq/L)	0.85^{a}	0.03	0.82^{ab}	0.02	0.78^{b}	0.03
Protein (%)	3.26^{A}	0.03	3.25^{A}	0.04	3.38^{B}	0.04
Casein (%)	2.59^{A}	0.03	2.57^{A}	0.02	2.66^{B}	0.03
Total solids (%)	12.20	0.08	12.09	0.10	12.23	0.10
Lactose (%)	4.56^{A}	0.02	4.54^{A}	0.01	4.45^{B}	0.02
Citric acid (%)	0.08	0.003	0.09	0.002	0.09	0.004
Acidity (SH)	6.20^{a}	0.10	6.12^{ab}	0.12	5.96^{b}	0.12

$^{aA,...}$Within rows means bearing different superscripts differ significantly at: small letters – P≤0.05; capitals – P≤0.01.
*FFA – free fatty acids.

in cow milk. These contradictions may be caused by health status of mammary gland. The lipolysis could have been caused by an increased permeability of the secretory epithelium of the glandular tissue, which in turn led to an increased level of the factor activating spontaneous lipolysis of milk fat. An intensification of the lipolysis processes could be caused also by an increased activity of enzymes released from somatic cells and bacteria, which catalyse the breakdown of milk fat [Paape *et al*. 2007]. Goats used in the present study showed no clinical symptoms of *mastitis* and the SCC of their milk remained on a comparatively low level, keeping the standards for goats [Corrales *et al*., 2004, Bagnicka and Łukaszewicz 2008].

Summarizing, the goat milk analysed was characterized by a low level of FFA (<1.0 mEq/L) in relation to the SCC, animals' age and stage of lactation. The highest contents of FFA and fat were recorded in the last stage of lactation, whereas the highest milk yield was observed in primiparous does. The milk obtained from this group of goats was, however, the most susceptible to lipolysis process.

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