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Basic chemical composition and the selected fat parameters of caprine milk from summer and autumn-winter feeding period*

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The aim of this study was to evaluate basic chemical composition, degree of milk fat dispersion and cholesterol content in milk of goats with regard to the production season. The examination included milk samples collected individually from the goats of White-Improved breed, from a whole milking. The study involved 70 samples, including 35 ones from the summer season (May-June) and 35 samples from the autumn-winter season (October-November). In all milk samples, the following parameters were determined: contents of fat, protein, lactose and dry matter, degree of milk fat dispersion and cholesterol concentration. It has been shown that in the summer season the animals produced significantly ($p \leq 0.01$) more milk (by 1.82 kg). Milk collected in the autumn season, however, contained significantly ($p \leq 0.05$) more dry matter (by 0.74 percentage points), including fat (by 0.27 pp), protein (by 0.43 pp) and lactose (by 0.34 pp). The average diameter of the fat globules of goat milk produced in a peak of lactation (the summer season) was significantly ($p \leq 0.05$) larger (2.10 μm vs. 1.80 μm) compared to the end of lactation stage (the autumn-winter season). Milk obtained from the goats in the summer season contained significantly ($p \leq 0.01$) more cholesterol with regard to the milk collected in the autumn season (16.23 mg vs. 11.30 mg per 100 g of fat). The significant positive correlations between the daily milk yield and the average diameter of fat globules and its circumference (r=0.38 *), and the surface area (r=0.43***) were found. Moreover, the positive correlations between the cholesterol content and the daily milk yield of animals (r=0.38**) and the negative between the cholesterol content and the lactose concentration (r=–0.32*) were stated.**

KEY WORDS: caprine milk / milk fat / fat globules / cholesterol

Goat milk has been a valuable component of human diet for more than 10 thousand years [16, 18]. Its basic chemical composition is similar to that of cow's milk; however, there are some differences in terms of the qualitative composition of protein and fat [19]. In terms of the fat fraction interspecies differences concern both the fatty acid

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profile as well as the degree of milk fat dispersion. Fat is synthesised in milk-producing cells of the mammary gland in the form of small globules surrounded by the three-layered phospholipid membrane [14]. The diameter of the fat globules in goat milk is smaller than that in cow's milk [17]. Attaie and Richter [1] reported that the average diameter of fat globules in goat milk is 2.76 µm (ranging from 0.73 to 8.58 µm), while in cow's milk it is 3.51 µm (from 0.92 to 15.75 µm). The size of fat globules has a significant effect on digestibility of milk fat [3]. The high degree of milk fat dispersion promotes better access of lipolytic enzymes to the small fat globules, which in turn is connected with greater digestibility of goat milk [2]. This milk is also characterised by a higher concentration of short- and medium chain [15], mono- (MUFA) and polyunsaturated (PUFA) fatty acids, exhibiting a beneficial effect on human health [8]. Lopez-Aliaga et al. [10] also indicated greater hypocholesterolemic properties of goat milk. This finding is based on the fact that a 17% reduction was recorded in blood cholesterol level of rats after their diet was supplemented with goat milk in comparison to the cholesterol level of those receiving cow's milk.

The aim of this study was to assess the basic chemical composition, the degree of milk fat dispersion and cholesterol level in goat milk depending on the production season.

Materials and methods

Material for analyses comprised milk samples collected individually from whole milking of White Improved goats. A total of 70 samples were analysed, including 35 in the summer season (May-June) and 35 in the autumn season (October-November). When collecting samples care was taken to use only animals with health mammary glands.

In the summer season feeding was based mainly on fresh pasture forage supplemented with hay. In the autumn-winter season the diet was based on haylage and hay. The feed ration was supplemented with concentrate in the form of ground grain. Daily milk yield of goats was determined by weighing all the milk collected from the morning and evening milkings.

In each milk sample the basic chemical composition was determined, i.e. contents of fat, protein, lactose and milk solids (using an Infrared Milk Analyzer), as well as the degree of milk fat dispersion (by microscopic examination in two fields of vision at x1000 magnification using the Motic Image Plus 2.0 programme). Cholesterol content was determined following the method developed by the Institute of Animal Production in Balice as modified by the authors (using a UV–VIS Carry 300 spectrophotometer).

Results were analysed statistically using the StatSoft Inc. STATISTICA ver. 6 programme applying the one-way analysis of variance with the production season as the source of variation. Significance of differences between means for individual parameters was determined by Fisher's LSD test at p (alfa)=0.05 and p=0.01. Moreover, Pearson's linear correlation coefficients were established. Significance of obtained correlations was determined at p=0.05 (*); p=0.01(**) and p=0.001(***).

Results and discussion

In goats lactation is closely connected with the production season. The onset of lactation typically takes place in the first months of the year, when animals are still fed preserved

feeds. At the peak of lactation (the summer months) the feed ration is typically based on fresh pasture forage, while at the final stage of lactation (autumn) preserved roughage (haylage, hay) is used again. It results from data given in Table 1 that in the summer season the animals produced significantly ($p \leq 0.01$) more milk (2.86 kg vs. 1.04 kg). The high milk yields of goats in the summer season may thus be linked not only with access to fresh pasture forage, but also with peak lactation. In turn, milk produced in the autumn season contained significantly ($p \leq 0.05$) more solids (by 0.74 percentage points), including fat (by 0.27 pp), protein (by 0.43 pp) and lactose (by 0.34 pp). These results are comparable to those reported in a study by Bernacka [5], which showed that milk obtained from White Improved goats in the winter season (October-April) was characterised by a high content of fat (by 0.33 pp), protein (by 0.22 pp) and lactose (by 0.18 pp) in comparison to that produced in the summer season (May-September). In contrast, Szymanowska et al. [20] reported slightly higher contents of fat and protein, at the simultaneously lower content of lactose in milk collected in the summer season. However, these differences were not confirmed statistically.

The degree of milk fat dispersion affects not only its digestibility, but it also determines the final quality of resulting products, e.g. cheese. Goudedranche et al. [7] reported that cheese produced from milk containing fat of smaller globules is softer in comparison to that obtained from the raw material, in which fat globules are larger. Moreover, smaller fat globules are more readily accessible for bacterial milk enzymes during fermentation and ripening, thus influencing taste quality attributes and texture parameters of the final product.

It results from data presented in Table 2 that the average diameter of fat globules in goat milk produced at the peak of lactation (the summer season) was significantly ($p \leq 0.05$) larger (2.10 µm vs. 1.80 µm) in comparison to its final phase (the autumn season). Analogous dependencies were recorded for the circumference of fat globules and their surface

Table 1
Daily yield and basic chemical composition of goat milk with consideration of the production season

Specification		Season	
		summer (lactation peak)	autumn (lactation end)
n		35	35
Daily milk yield (kg)	x	2.88^{A}	1.10^{B}
	SD	0.78	0.79
Fat (%)	x	3.39^{a}	3.66^{b}
	SD	0.45	0.50
Protein (%)	x	2.65^{A}	3.08^{B}
	SD	0.29	0.39
Lactose (%)	x	4.11^{A}	4.45^{B}
	SD	0.33	0.37
Dry matter (%)	x	10.97^{a}	11.71^{b}
	SD	1.07	1.21

A, B – differences between seasons significant at $p \leq 0.01$; a, b – significant at $p \leq 0.05$

area. The presented differences in the degree of milk fat dispersion may be related to the differences in productivity of goats observed in individual seasons. In the summer period goats produced significantly ($p \leq 0.01$) more milk (over two-fold in comparison to the autumn months), which was connected with the need to sythesise considerable amounts of components for the milk fat globule membranes. Secretion of small milk fat globules is a biological process, requiring production of large quantities of material for the formation of the membrane covering their surface. At a higher milk yield the activity of milk producing cells synthesising the membrane material is no longer sufficient, as a result of which the diameter of fat globules increases. As a consequence, nanny goats secreting fat formed into larger globules are characterised by a potentially lower metabolic activity of milk producing cells in comparison to goats secreting fat in the form of small globules [9]. Results recorded in this study confirm these theses. Significant, positive correlations were shown between daily yields of goats and the average diameter of fat globules and their circumference (r=0.38***), as well as their surface area (r=0.43***).

Fat globules are surrounded by the membrane of 10-50 nm in thickness, which composition and structure are dependent on the secretion mechanism [11]. Cholesterol is one of the components found in the fat globule membranes.

Significant differences were shown in milk cholesterol contents depending on the production season (tab. 2). Milk obtained from goats in the summer contained significantly ($p \leq 0.01$) more cholesterol in comparison to that produced in the autumn (16.23 vs. 11.30 mg/100 g fat). Mayer and Fiechter [12] showed that the mean cholesterol content in milk produced by Austrian goats was 12.4 mg/100 g milk, ranging from 8.0 to 21.9 mg/100 g.

Table 2

The selected parameters of milk fat with consideration of production season

Specification		Season	
		summer (lactation peak)	autumn (lactation end)
n		35	35
Degree of milk fat dispersion			
average diameter of milk globules (μm)	x	2.10^{b}	1.80^{a}
	SD	0.40	0.21
circumference of milk fat globule membranes in field of vision (μm)	x	6.60^{B}	5.64^{A}
	SD	1.27	0.66
surface of milk fat globules in field of vision (μm)	x	4.59^{B}	3.08^{A}
	SD	1.70	0.76
Cholesterol (mg/100 ml)	x	16.23^{B}	11.30^{A}
	SD	4.33	3.94

A, B – differences between seasons significant at $p \leq 0.01$; a, b – significant at $p \leq 0.05$

Table 3
Correlation coefficients for the analyzed parameters of goat milk

Traits	Fat (%)	Protein (%)	Lactose (%)	Dry matter (%)	Daily milk yield (kg)	Surface of milk fat globules in field of vision (μm^2)	Circumference of milk fat globule membranes in field of vision (μm))	Average diameter of milk globules (μm)
Cholesterol (mg/100 ml)	0.03	–0.27	–0.32*	–0.03	0.38**	0.22	0.17	0.17
Fat (%)		0.51***	0.33*	0.91***	–0.22	0.03	0.07	0.06
Protein (%)			0.70***	0.63***	–0.47***	–0.07	–0.04	–0.04
Lactose (%)				0.49***	–0.26*	0.11	0.12	0.12
Dry matter (%)					–0.25*	0.11	0.14	0.13
Daily milk yield (kg)						0.43***	0.38**	0.38**
Surface of milk fat globules in sight area (μm^2)							0.99***	0.99***

*Significant at $p \leq 0.05$; ** – at $p \leq 0.01$; *** – at $p \leq 0.001$

In their studies Bernacka and Simińska [6] and Park [13] reported that 100 ml goat milk contain on average 12-17 mg cholesterol. In turn, Bernacka [4] when comparing the composition of milk collected from Polish Improved White and Fawn goats in the summer and winter seasons recorded higher cholesterol contents in the winter season. However, the differences were statistically non-significant.

Data contained in Table 3 indicate a significant, positive dependence between milk cholesterol content and daily milk yields of animals (r=0.38**) and a negative correlation with lactose concentration (r=−0.32*). These dependencies are confirmed by the results of studies conducted by Tomaszewski [21] on cow's milk, showing that milk cholesterol level increased markedly with an increasing milk yield of the animals.

Significant, very high correlations (r=0.99***) were found between surface areas of fat globules in the field of vision and the diameters and circumferences of fat globule membranes (Table 3). Additionally, positive dependencies were observed between fat content and the concentration of protein (r=0.51***), lactose (r=0.33*) and milk solids (r=0.91***) as well as protein content and the concentration of lactose (r=0.70***) and milk solids (r=0.63***). In contrast, negative significant dependencies were observed between daily milk yields and contents of protein (r=−0.47***) and lactose (r=−0.26*).

Summing up it may be stated that the production season, which in the case of goats is closely related with the stage of lactation, is a significant factor differentiating the chemical composition of milk and the degree of milk fat dispersion. Goat milk collected in the summer season is characterised by a slightly lower concentration of basic components, i.e. fat and protein. In turn, milk produced in the autumn season has a higher fat content, but it may be more readily digestible thanks to the higher degree of dispersion, while at the same time containing less cholesterol.

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