TÜBİTAK

Turkish Journal of Veterinary and Animal Sciences

http://journals.tubitak.gov.tr/veterinary/

Research Article

Turk J Vet Anim Sci
(2020) 44: 720-728
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doi:10.3906/vet-1912-102

Differences in physico-chemical parameters of goat milk depending on breed type, physiological and environmental factors

Joanna BARŁOWSKA, Robert PASTUSZKA, Jolanta KRÓL*, Aneta BRODZIAK, Anna TETER, Zygmunt LITWIŃCZUK

Institute of Quality Assessment and Processing of Animal Products, University of Life Sciences in Lublin, Akademicka, Lublin, Poland

Received: 02.01.2020 • **Accepted/Published Online:** 15.03.2020 • **Final Version:** 02.06.2020

Abstract: The objective of the research was to analyse the technological parameters of milk and assess the impact of selected factors, i.e. the genetic group of goats (improved goats—Saanen crosses vs various crossbreds of unknown genetic origin—breedless goats with different coat for which no breeding books were kept), production season (winter, spring/summer, and autumn), which was associated with the stage of lactation (1, 2, and 3), the region where the goats were raised (upland or mountainous areas) and daily yield (< 1.0, 1.0–2.0, or > 2.0 kg). A total of 480 milk samples were evaluated (203 milk samples from Saanen crosses and 277 from various crossbreds of unknown genetic origin). The milk was tested for proximate chemical composition, casein content, active and potential acidity, coagulation time, and heat stability. All factors analysed were found to significantly affect daily milk yield, potential acidity and composition (contents of fat, nonfat dry matter, total protein, and casein). Goat crossbreds of unknown genetic origin produced milk with better chemical composition, i.e. higher contents of fat, nonfat dry matter, total protein, and casein, and technological parameters—higher heat stability (despite lower daily yield) than Saanen crosses, especially in autumn (end of lactation). The region of production was also significant. Goats raised in mountainous areas produced milk with a more favourable chemical composition, i.e. higher content of dry matter and protein, including casein, but with lower heat stability, in most cases irrespective of the production season. As daily milk yield increased, there was a decrease in the content of fat and nonfat dry matter, including total protein and casein, as well as a reduction in the rennet clotting time. Analysed factors and their interactions play an important role in shaping the chemical composition of goat milk and determine its technological usefulness.

Key words: Goat milk, chemical composition, technological parameters, casein, correlation

1. Introduction

In recent years, goat milk has gained in importance in the human diet, alongside cow milk. Global production of goat milk amounted to 18.7 million tonnes in 2018 and has increased by 46% since 2000. Its current share in global production among the five species included in FAO statistics is 2.3% (third after cow and buffalo milk). India is the world's largest producer of goat milk–6.1 million tonnes in 2018, accounting for about 33% of global production. In Poland, goat's milk is the second most important dairy raw after cow's milk. The size of its production in 2018 amounted to 7.5 thousand tonnes which represents a small part (less than 1%) in the production of this raw material in Europe [1].

In developing countries, goat milk plays an important role in human nutrition, helping to combat malnutrition, especially among young children [2]. In developed countries, interest in goat milk is growing because it is believed to have beneficial (functional) properties for human health [3]. Moreover, the number of connoisseurs of goat milk products (mainly cheese and yogurt) is on the rise [4,5].

Raw milk used for processing should have a suitable chemical composition, physical characteristics and technological parameters, which guarantees finished products of a high standard. However, considerable differences between goat breeds are observed in milk composition and cheese yield [6–8].

An important parameter determining the suitability of milk for the production of rennet cheese is its rennet clotting time. Parameters such as casein content, the ratio of calcium to nitrogen compounds, and the size of the casein micelles determine both the rate of curd formation and the degree of its firmness. According to Cecchinato and Bittante [9], the main components affecting the coagulation properties of milk and at the same time contributing to cheese yield are fat and protein, in particular casein. Stocco et al. [10] have found that milk rich in fat

* Correspondence: jolanta.krol@up.lublin.pl

had better coagulation properties, while coagulation of protein-rich milk was delayed. They also reported that a higher casein-to-protein ratio (casein number) improved milk coagulation. However, the rennet clotting time and curd firming time of goat milk is markedly shorter than for cow milk [11].

Technological processes used in dairy plants often require high temperatures. Raw milk subjected to such treatments should have high heat stability. This technological parameter determines the predisposition of milk to retain colloidal properties, in particular those of proteins, at high temperatures. Processing of milk with low heat stability may lead to sedimentation of denatured proteins in the finished product, or even their jellification during storage [12]. Goat milk is generally highly sensitive to heat treatment. Its high content of ionic calcium and low degree of micellar solvation reduce the heat stability of goat milk, which is much lower than that of cow milk [13,14].

Certain elements of the goat population have become international breeds that are suitable for intensive farming, but a significant portion of the population is adapted to extensive production systems and environmental conditions that are often adverse for other livestock species. Locally raised goat populations produce milk which is generally used for the production of regional dairy products [6,7].

The aim of the study was to assess the impact of selected factors, i.e. the genetic group of goat (improved goats—Saanen crosses vs various crossbreds of unknown genetic origin—breedless goats with different coat), production season (winter, spring/summer, or autumn), which is associated with the stage of lactation (1, 2, and 3), the region where the goats are raised (upland or mountainous areas) and daily yield (<1.0, 1.0–2.0, or >2.0 kg), on the suitability of milk for processing, i.e. the content of fat, total protein, and casein, rennet clotting time, and heat stability.

2. Materials and methods

2.1. Research material

The research material consisted of the milk of goats kept on four farms, of which two were located in upland areas—Central Beskidian Piedmont (Dynowskie Foothills) (300–500 m a.s.l.; 49° 88′ N, 22° 24′ E) and two in mountain areas—in the Beskids (500-1,000 m a.s.l.; 49° 25′ N, 22° 35′ E) in Poland. A total of 480 milk samples were taken, of which 142 were from upland areas and 338 from mountainous areas. Two genetic groups of goats were distinguished, i.e. Saanen crosses (203 milk samples) and various crossbreds of unknown genetic origin for which no breeding books were kept (277). Each of these groups was raised in upland and mountainous areas. The samples were collected within 1 year in three production seasons, which, in goats, are largely associated with the stage of lactation: winter (start of lactation)—166 samples, spring/summer (midlactation)—161, and autumn (end of lactation)—153.

In winter, the goats were fed hay and haylage, and during lactation they were given on-farm concentrate feed consisting of cereal meal (oats and wheat). In the spring/summer season, the diet was based on green forage, and the feed ration was supplemented with concentrate feed as described above. In autumn, the diet consisted of hay and haylage, as well as a small amount of green forage, and during lactation the goats received concentrate feed as above (Table 1). The goats had uninterrupted access to drinking water and licks.

Milk samples of approximately 300 mL were taken from one complete milking procedure from each goat, and the daily yield of the goats was determined by measuring (in kg) all milk obtained from one morning or evening milking session and proportionally (based on an interview with the farmer who monitored the volume of milk obtained) by calculating its volume from the other milking session.

2.2. Laboratory analyses

The following were determined in the milk samples: proximate chemical composition, i.e. content of fat, total

Table 1. Nutritional value of fodder used in feeding of goats (in 1 kg of dry matter).

Specification	Dry matter (%)	Total protein (g)	Crude fibre (g)	UFL[1]	PDIN[2] (g)	PDIE[3] (g)
Pasture forage	17.77	123.73	270.23	0.98	78.14	91.00
Haylage	54.97	161.63	173.63	0.97	101.43	94.28
Hay	89.57	93.10	332.01	0.72	57.49	72.63
Wheat and oat ground grain	87.62	126.31	74.85	1.15	85.35	101.73

[1]UFL: feed unit for lactation
[2]PDIN: protein truly digestible in the small intestine when N limits microbial protein synthesis
[3]PDIE: protein truly digestible in the small intestine when energy limits microbial protein synthesis

protein, lactose, and dry matter (which were used to calculate the content of nonfat dry matter and the protein-to-fat ratio) with a Bentley Infrared Milk Analyzer; casein content by the AOAC method [15]; active acidity (pH) with the Elmetron CP-401 pH meter; potential acidity (°SH) by the titration method according to PN-86/A-86122; heat stability of milk at 140 °C in a TEWES-BIS oil bath according to White and Davies [16], and coagulation time by Schern's method.

2.3. Statistical analysis

The results were analysed statistically using StatSoft Inc. Statistica software, by one- and two-way analysis of variance with interaction. The significance of differences between means for individual parameters was determined by the Tukey test at $P \leq 0.05$ and $P \leq 0.01$.

The statistical analysis included the following factors:

· genetic group of goats (2 groups: Saanen crosses and various crossbreds of unknown genetic origin),

· region where the goats were raised (2 regions: upland and mountain),

· production season/stage of lactation (3 seasons: winter—stage 1, spring/summer—stage 2, autumn—stage 3),

· daily yield (< 1.0; 1.0–2.0; > 2.0 kg).

Pearson correlation coefficients for the milk and cheese parameters were calculated as well. The significance of the correlations was determined at $P \leq 0.05$, $P \leq 0.01$, and $P \leq 0.001$.

3. Results and discussion

An important factor affecting goat milk yield and the properties of the raw milk is the genetic group. Saanen crosses had a significantly ($P \leq 0.01$) higher daily milk yield than the crossbreds of unknown genetic origin: 1.86 and 1.57 kg, respectively (Table 2). On the other hand, the raw milk obtained from the crossbreds had a higher concentration of fat (by 0.57 percentage point, pp) and nonfat dry matter (by 0.44 pp), including protein (by 0.46 pp), and casein (by 0.33 pp), than that of the Saanen crosses. The milk of the latter had a higher ($P \leq 0.05$) share of casein in the total protein (81.34% vs 80.17%). Studies by Barłowska et al. [6] and Brodziak et al. [17] also indicate a lower content of basic constituents in the milk of improved, high-performance goats than in that of goats of unknown genetic origin, i.e. for which no breeding books were kept. The significantly higher content of protein, including casein, in the milk of goats of unknown genetic origin can be associated with the genotype of these animals. In the population of goats' crosses with unknown genetic origin, there is generally a higher frequency of αs_1-casein genes A, B, and C, i.e. 'strong' genes [18], which determine a higher level of synthesis of this protein fraction, and thus of casein and total protein [19–22]. Moreover, the study by Mestawet et al. [23], conducted in Ethiopia, showed that milk from Toggenburg-Arsi-Bale cross was lower in total solids 13.9% and fat 3.7% ($P < 0.001$), than Arsi-Bale, Boer, and Somali goats which had 16.3%, 15.4%, and 14.5% total solids, and 5.2%, 4.7%, and 4.9% fat, respectively.

The genetic group was also shown to influence the technological parameters of the milk. The acidity of milk, which indicates its freshness, is important in terms of suitability for processing. Fresh goat milk should have an active acidity (pH value) from 6.08 to 7.06 and titratable acidity from 4.4 to 8.5 °SH [24]. The milk of both the improved goats (Saanen crosses) and those of unknown origin met these criteria (Table 2). The acidity of milk expressed as a pH value determines the course of rennet coagulation [25]. These correlations were confirmed in the present research, in which a positive correlation coefficient of $r = 0.467$ ($P \leq 0.001$) was obtained between pH and rennet clotting time (Table 3). Milk obtained from goats of unknown genetic origin, which had a higher pH (6.85) had a significantly ($P \leq 0.01$) longer rennet clotting time (by 1:07 min) than the milk of improved goats. The milk of goats of unknown origin also had significantly ($P \leq 0.05$) higher heat stability (1:26 vs 1:18 min). These relationships are also confirmed by Wang et al. [26]. It should be noted that the short clotting time of goat milk contributes to the formation of a fragile curd with a tendency to fall apart and thus to a reduction in cheese yield, which is undesirable in cheese production. These technological parameters are closely linked to the content of total protein and especially casein [25], which is supported by the results of our research (Table 2). The significant effect of total content of protein, including casein, and nonfat dry matter on the coagulation properties of milk is indicated by statistically significant positive correlation coefficients (Table 3). Clark and Sherbon [27] have also reported significant positive correlation coefficients between clotting time and content of dry matter, nonfat dry matter, protein, and αs_1-casein. They suggest that milk with a higher content of dry matter, in particular protein, has a longer clotting time than milk with a lower content of dry matter. The authors also showed that a longer coagulation time contributes to the formation of a stronger, firmer curd, which was confirmed by the positive correlation coefficient between clotting time and clot firmness. However, they stress that a longer coagulation time will not always determine higher curd firmness. Danków and Pikul [24] emphasize that goat milk is exceptionally sensitive to high temperatures, due to the structure of the casein micelles, high ionic calcium content, and poor hydration of micelles. Barłowska et al. [28], in a comparison of improved coloured goats and various nonimproved crossbreds, obtained similar results to our own. The authors found a higher ($P \leq 0.01$) concentration of casein in the milk of goats of unknown genetic origin

Table 2. Technological parameters of goat milk in relation to various factors.

Parameter			Genetic group		Region		Production season—stage of lactation (diet)			Milk yield (kg)		
			Crossbreds of unknown origin	Improved goats (Saanen crosses)	Uplands	Mountains	1 (winter)	2 (spring/summer)	3 (autumn)	< 1.0	1.0–2.0	> 2.0
n (number of milk samples)			277	203	142	338	166	161	153	85	234	161
Daily yield (kg)		$\bar{x}$	1.57^{A}	1.86^{B}	1.73	1.67	1.76^{B}	2.13^{C}	1.15^{A}	0.69^{a}	1.47^{b}	2.53^{c}
		SD	0.72	0.75	0.75	0.75	0.67	0.71	0.49	0.17	0.31	0.45
Fat (%)		$\bar{x}$	3.97^{B}	3.40^{A}	3.29^{A}	3.91^{B}	3.76^{B}	3.25^{A}	4.19^{C}	4.54^{C}	3.72^{B}	3.31^{A}
		SD	1.03	0.63	0.74	0.94	0.74	0.53	1.17	1.17	0.81	0.61
Nonfat dry matter (%)		$\bar{x}$	8.49^{B}	8.05^{A}	8.11^{A}	8.38^{B}	8.14^{A}	8.06^{A}	8.73^{B}	9.01^{C}	8.26^{B}	7.99^{A}
		SD	0.78	0.44	0.56	0.72	0.45	0.46	0.88	0.87	0.57	0.44
Total protein (%)		$\bar{x}$	3.26^{B}	2.80^{A}	2.95^{A}	3.12^{B}	2.78^{A}	2.88^{A}	3.58^{B}	3.79^{C}	3.01^{B}	2.77^{A}
		SD	0.70	0.31	0.47	0.66	0.30	0.27	0.79	0.85	0.47	0.25
Casein (%)		$\bar{x}$	2.61^{B}	2.28^{A}	2.37^{A}	2.51^{B}	2.32^{A}	2.21^{A}	2.91^{B}	3.06^{C}	2.42^{B}	2.23^{A}
		SD	0.56	0.29	0.41	0.52	0.25	0.25	0.59	0.66	0.38	0.23
Percentage of casein in total protein (%)		$\bar{x}$	80.17^{a}	81.34^{b}	80.59	80.69	83.68^{C}	76.58^{A}	81.68^{B}	80.99	80.57	80.62
		SD	5.40	7.17	7.04	5.87	5.19	6.04	5.11	5.62	6.30	6.46
Protein-to-fat ratio		$\bar{x}$	0.85	0.86	0.92^{B}	0.82^{A}	0.77^{A}	0.91^{B}	0.89^{B}	0.86	0.84	0.86
		SD	0.19	0.22	0.19	0.20	0.18	0.15	0.24	0.23	0.21	0.17
Acidity	active (pH value)	$\bar{x}$	6.85^{b}	6.82^{a}	6.83	6.84	6.72^{A}	6.91^{B}	6.88^{B}	6.88^{B}	6.82^{A}	6.83^{A}
		SD	0.07	0.10	0.10	0.13	0.10	0.08	0.09	0.12	0.12	0.12
	potential (°SH)	$\bar{x}$	6.19^{B}	5.72^{A}	5.77^{A}	6.08^{B}	5.77^{A}	5.55^{A}	6.70^{B}	6.66^{C}	6.01^{B}	5.62^{A}
		SD	1.08	0.87	0.99	1.02	0.92	0.75	1.02	1.16	1.01	0.75
Rennet clotting time (min)		$\bar{x}$	$3:52^{B}$	$2:45^{A}$	3:27	3:22	$2:53^{A}$	$3:16^{A}$	$4:04^{B}$	$4:48^{B}$	$3:11^{A}$	$2:58^{A}$
		SD	2:33	1:13	2:14	2:08	1:45	1:07	3:02	3:20	1:48	1:28
Heat stability (min)		$\bar{x}$	$1:26^{b}$	$1:18^{a}$	$1:16^{A}$	$1:38^{B}$	$1:12^{A}$	$1:27^{B}$	$1:30^{B}$	1:28	1:24	1:18
		SD	0:48	0:35	0:35	0:54	0:30	0:39	0:56	0:56	0:45	0:31

a, b, A, B: statistically significant differences within a given factor; a, b: at $P \leq 0.05$; A, B: at $P \leq 0.01$.

Table 3. Pearson correlation coefficients for parameters of goat milk.

Parameter	Fat	Total protein	Protein-to-fat ratio	Casein	Percentage of Casein in total protein	Nonfat dry matter	Acidity pH	Acidity °SH	Rennet clotting time	Heat stability
Daily yield	−0.539 ***	−0.546 ***	0.218 *	−0.557 ***	0.135	−0.468 ***	−0.100	−0.431 ***	−0.281 **	−0.152
Fat		0.592 ***	−0.666 ***	0.597 ***	−0.145	0.726 ***	−0.069	0.473 ***	0.142	−0.099
Total protein			0.164	0.928 ***	−0.425 ***	0.879 ***	0.335 ***	0.614 ***	0.418 ***	0.277 **
Protein-to-fat ratio				0.098	−0.194 *	−0.081	0.310 ***	−0.019	0.149	0.304 ***
Casein					−0.061	0.826 ***	0.245 **	0.612 ***	0.368 ***	0.244 **
Percentage of casein in total protein						−0.354 ***	−0.322 ***	−0.140	−0.234 **	−0.151
Non-fat dry matter							0.234 **	0.472 ***	0.280 **	0.182 *
Acidity pH								−0.230 *	0.467 ***	0.287 ***
Acidity °SH									0.026	0.144
Rennet clotting time										0.297 ***

***: $P \leq 0.001$; **: $P \leq 0.01$; *: $P \leq 0.05$

than in that of improved goats—Saanen crosses (2.79% vs 2.41%). Moreover, the milk of these animals had a significantly ($P \leq 0.01$) longer rennet clotting time (2:56 vs 2:15 min.) and withstood heat treatment longer (1:40 vs 0:50 min; $P \leq 0.01$). In an earlier study, Barłowska et al. [29] showed both significantly ($P \leq 0.01$) higher heat stability and a longer clotting time for the milk of white goats of unknown origin than that of Polish White goats improved with the Saanen breed. Strzałkowska et al. [19], on the other hand, found a higher content of casein in the milk of Polish White Improved goats, by 0.3 pp (strong variants of αs_1-casein) and by 0.24 pp (intermediate variants of αs1-casein), compared to our results for improved goats (Saanen crosses).

The region where milk is obtained is also significant for its technological parameters (Table 2). Milk obtained from goats raised in mountainous areas was found to have significantly ($P \leq 0.01$) higher content of fat (by 0.62 pp) and protein (by 0.17 pp), including casein (by 0.14 pp), than that of goats raised in upland areas. It also had significantly higher heat stability (1:38 vs 1:16 min). On the other hand, the protein-to-fat ratio proved to be significantly higher in the raw milk from the uplands (0.92 vs 0.82). In a comparison of mountain and upland areas, Kędzierska-Matysek et al. [30] found a significantly higher content ($P \leq 0.01$) of protein in the raw milk obtained from the mountains, as in our research. Contrasting results have been reported by Žan et al. [31], who obtained lower protein content in the milk of goats grazing in the mountains compared to upland areas. It is worth noting, however, that the authors were comparing two different breeds of goats (Saanen in the uplands and Alpine in the mountains), which most likely influenced their results. The available literature lacks studies on the suitability of goat milk from different altitudes for processing.

The yield and technological parameters of milk are also affected by the season when it is acquired (Table 2). As goats are seasonal in their sexual activity, the production season is associated with the stage of lactation. Lactation usually begins in the first months of the year, when the animals are fed with preserved feed (hay and silage), i.e. the winter feeding period. The peak of lactation occurs in the summer, when the diet consists mainly of green forage. At this time there is a dramatic increase in milk yield in goats. The end of lactation takes place in the autumn, when the diet of goats again consists of preserved roughage, and sometimes occasional pasture forage. Analysis of the data in Table 2 reveals a characteristic lactation curve for daily yield. In the first lactation period (winter feeding), milk production was 1.76 kg, followed by a production peak (2.13 kg) during the pasture feeding period (second stage of lactation), and then (third stage of lactation) a significant ($P \leq 0.01$) decline in milk yield (1.15 kg), when the goats were slowly entering the dry period and the share of preserved feed in the feed ration was increasing. A significantly higher content of basic milk constituents, i.e. fat (by 0.94 pp) and protein, including casein (by 0.70 pp), was noted in the milk obtained at the end of lactation (autumn) compared to the second stage (spring and summer). Mioč et al. [32] also noted the highest fat and protein content in the last stage of lactation. Strzałkowska et al. [2] obtained similar trends in their analysis of the daily yield and chemical composition of the milk of Polish White Improved goats during the entire lactation. Milk yield increased in the first months of lactation, reaching a peak in the fourth month (3.05 kg), and then as lactation progressed the yield decreased to 1.05 kg in the tenth month. Other authors [6,33] have also demonstrated significantly ($P \leq 0.01$) higher daily yield of goats in the summer than in the winter or autumn. The much higher milk yield of goats during the summer may be due not only to access to fresh pasture, but also to the peak stage of lactation. Mestawet et al. [23], in an assessment of four goat breeds, reported identical relationships to those obtained in our study for milk yield and the concentration of dry matter constituents of milk during the course of lactation. The highest milk yield with the lowest dry matter content, including protein and fat, was noted in the second stage of lactation. The analysis of technological parameters of goat milk over the course of lactation (Table 2) revealed the lowest active and potential acidity (statistically significant at $P \leq 0.01$) for the milk obtained in the spring and summer (second stage of lactation), as compared to the winter and autumn. As lactation progressed, there was a significant ($P \leq 0.01$) increase in the rennet coagulation time of the milk (2:53; 3:16; 4:04 min.), and in heat stability (1:12; 1:27; 1:30 min). The significantly longer enzyme coagulation time of goat milk is more favourable, as it leads to a firmer curd, as noted by Barłowska et al. [6,28], and this in turn could have been linked to the higher content of nonfat dry matter, including casein, in the autumn. Other authors [30,34,35] have also observed an increase in casein content in milk over the course of lactation and its highest concentration at the end of lactation. Similar results regarding milk coagulation time have been reported by Kuchtík et al. [36], who noted the shortest clotting time at the start of lactation (58 and 50 s on days 35 and 68, respectively).

Productivity is an important factor determining the profitability of farms keeping milking animals, including goats. In our research, as daily yield increased there was a significant ($P \leq 0.01$) decrease in fat and nonfat dry matter content in the milk, including protein and casein (Table 2), which is also indicated by the Pearson correlation coefficients (Table 3). Daily yield was significantly ($P \leq 0.001$) negatively correlated with content of fat ($r = -0.539$) and nonfat dry matter ($r = -0.468$), including protein ($r = -0.546$) and casein ($r = -0.557$). The correlation coefficient between daily yield and fat content in the present study is almost identical to the value obtained for these parameters by Strzałkowska et al. [19] ($r = -0.539$ and $r = -0.55$, respectively). The correlations between daily yield and basic goat milk constituents obtained by Wolanciuk et al. [33] also correspond closely to those obtained in our research. The acidity of the milk and the indicators of its suitability for processing were also determined by productivity. The raw milk obtained from goats with the lowest milk yield (below 1.0 kg) had significantly ($P \leq 0.01$) the highest active (6.88 °SH) and potential (6.66 °SH) acidity, rennet clotting time (4:48 min), and heat stability (1:28 min). In the case of clotting time, there was a significant ($P \leq 0.01$) negative correlation ($r = -0.281$) with daily yield (Table 3). It is difficult to compare the results to those of studies by other authors, due to the lack of available literature in this area.

Table 4 presents a more detailed analysis, which takes into account the genetic group and the production season (stage of lactation). The results indicate that in the first stage of lactation the daily yield of goats from the two genetic groups was similar (the difference, in favour of Saanen crosses, was only 0.12 kg). At peak lactation (stage 2) there was an increase in milk production, which was more pronounced in the Saanen crosses than in the goats of unknown origin (by 0.60 vs 0.24 kg). In the third stage of lactation, yield decreased by 1.0 kg of milk in both groups, but the Saanen crosses produced 0.47 kg more. The milk of goats of unknown genetic origin, irrespective of the production season, had a higher concentration of components that are valuable for processing, i.e. fat and protein, including casein, with the highest values recorded in the last stage of lactation (autumn). The rennet clotting time of this milk was longer as well, reaching the highest value in stage 3, which is 5:24 min. The milk of Saanen crosses clotted more than twice as fast (2:34 min). In addition, significant ($P \leq 0.001$) interactions of the goat breed group and production season were found for fat content and nonfat dry matter, including protein and casein, as well as the share of casein in the total protein, acidity expressed by pH, and rennet clotting time. Barłowska et al. [29] also showed interactions between breed and production season for dry matter, including protein and fat.

Table 4. Selected technological parameters of the milk of goats of unknown genetic origin and improved goats in relation to the season of production.

Parameter			Production season—stage of lactation (diet)						Effect of factor		
			1 (winter)		2 (spring/summer)		3 (autumn)				
			Goats of unknown genetic origin	Improved goats (Saanen crosses)	Goats of unknown genetic origin	Improved goats (Saanen crosses)	Goats of unknown genetic origin	Improved goats (Saanen crosses)	Gr	PS	Gr×PS
n (number of milk samples)			95	71	101	60	81	72			
Daily yield (kg)		x̄	1.71	1.83	1.95^{A}	2.43^{B}	0.93^{A}	1.40^{B}	***	***	nd
		SD	0.65	0.70	0.66	0.69	0.37	0.50			
Nonfat dry matter (%)		x̄	8.22	8.02	8.07	8.06	9.33^{B}	8.06^{A}	***	***	***
		SD	0.46	0.42	0.48	0.44	0.71	0.46			
Fat (%)		x̄	3.87^{b}	3.61^{a}	3.25	3.26	4.98^{B}	3.31^{A}	***	***	***
		SD	0.68	0.80	0.59	0.42	0.99	0.55			
Total protein (%)		x̄	2.88^{B}	2.64^{A}	2.94	2.79	4.11^{B}	2.97^{A}	***	***	***
		SD	0.29	0.26	0.27	0.25	0.68	0.31			
Casein (%)		x̄	2.36	2.27	2.29^{B}	2.06^{A}	3.30^{B}	2.46^{A}	***	***	***
		SD	0.26	0.23	0.20	0.26	0.51	0.24			
Percentage of casein in total protein (%)		x̄	82.04^{A}	85.87^{B}	78.15^{B}	73.95^{A}	80.50^{a}	83.02^{b}	**	***	***
		SD	5.55	3.68	5.36	6.23	4.38	5.56			
Protein-to-fat ratio		x̄	0.76	0.77	0.93	0.87	0.85	0.93	nd	***	*
		SD	0.15	0.22	0.16	0.12	0.21	0.26			
Acidity	pH	x̄	6.77^{B}	6.66^{A}	6.90	6.91	6.88	6.89	**	***	***
		SD	0.09	0.08	0.06	0.09	0.10	0.06			
	°SH	x̄	5.86	5.64	5.71^{b}	5.29^{a}	7.22^{B}	6.14^{A}	***	***	**
		SD	0.90	0.92	0.70	0.76	0.99	0.71			
Rennet clotting time (min)		x̄	3:14	2:26	3:13	3:22	5:24^{B}	2:34^{A}	***	**	***
		SD	2:11	0:42	0:57	1:22	3:29	1:20			
Heat stability (min)		x̄	1:16	1:08	1:31^{b}	1:20^{a}	1:32	1:27	*	**	nd
		SD	0:35	0:20	0:45	0:26	1:01	0:49			

A, B: statistically significant differences between genetic groups within a production season at $P \leq 0.01$; a, b: statistically significant differences between genetic groups within a production season at $P \leq 0.05$; Gr: genetic group, PS: production season; Gr × Sp: interaction of genetic group and production season; ***: $P \leq 0.001$; **: $P \leq 0.01$; *: $P \leq 0.05$; nd – not detected

To sum up, variation in milk composition and technological parameters was influenced by the genetic group, the production season combined with the stage of lactation, daily yield, and the region where the goats were raised. Goat crossbreds of unknown genetic origin, despite lower daily yield, produced milk with better chemical composition and technological parameters compared to the milk of improved goats. Milk obtained in autumn (end of lactation) had the highest concentration of fat and nonfat dry matter, including total protein and casein, with a high proportion of casein in the total protein and protein-to-fat ratio, as well as the longest rennet clotting time and heat stability. Goats raised in mountainous areas produced milk with a more favourable chemical composition, i.e. higher content of fat, protein, including casein, dry matter, and nonfat dry matter, with lower heat stability, usually irrespective of the production season. As daily milk yield increased, there was a decrease in the content of fat and nonfat dry matter, including total protein and casein, as well as a reduction in the rennet clotting time. Rennet coagulation time was negatively correlated with daily yield and the share of casein in the total protein, and positively with the content of nonfat dry matter, including total protein and casein, active acidity, and heat stability.

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