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ORIGINAL ARTICLE

Seasonal variations of Saanen goat milk composition and the impact of climatic conditions

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Abstract The aim of this research was to investigate the effect of climatic conditions and their impact on seasonal variations of physico-chemical characteristics of Saanen goat milk produced over a period of 4 years. Lactation period (early, mid and late) and year were considered as factors that influence physico-chemical composition of milk. Pearson's coefficient of correlation was calculated between the physico-chemical characteristics of milk (fat, proteins, lactose, non-fat dry matter, density, freezing point, pH, titrable acidity) and climatic condition parameters (air temperature, temperature humidity index—THI, solar radiation duration, relative humidity). Results showed that all physico-chemical characteristics of Saanen goat milk varied significantly throughout the lactation period and years. The decrease of fat, protein, non-fat dry matter and lactose content in goat milk during the mid-lactation period was more pronounced than was previously reported in the literature. The highest values for these characteristics were recorded in the late lactation period. Observed variations were explained by negative correlation between THI and the physico-chemical characteristics of Saanen goat milk. This indicated that Saanen goats were very prone to heat stress, which implied the decrease of physico-chemical characteristics during hot summers.

Keywords Seasonal variations · Goat milk · Climatic conditions · Physico-chemical characteristics · Temperature humidity index

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Introduction

Climate characteristics such as air temperature, solar radiation, minimum relative humidity, air flow and their interactions contribute to animal performance. The quality and quantity of milk compounds is generally a result of complex interactions of variables. These are not fixed and they can change with the time of the year, environmental conditions, and climate variability (Milani et al. 2015).

The influence of climatic conditions on seasonal variations of the composition of cow milk has been widely studied. Therefore, seasonal variations of cow milk fat content are well recognized, with milk fat during summer months averaging 0.4 percentage units less than milk fat in winter months (Jensen et al. 1991). Also, it is known that cow milk protein content is higher during fall and winter than in spring and summer (Lindmark-Månsson et al. 2003; Ng-Kwai-Hang et al. 1985), and that all mineral levels in milk are significantly affected by season (Chen et al. 2014; Poulsen et al. 2015). Relative humidity and maximum and minimum temperatures account for significant amounts of variability (1–6%) in the percentages of cow milk constituents (Rodriquez et al. 1985).

Despite the fact that world production of goat milk is the second largest of all non-cattle milk (Faye and Konuspayeva 2012), data regarding the effect of climatic conditions and their seasonal variations on the composition and quality of goat milk is limited. This is even more surprising knowing that significant variation of goat milk composition throughout the year strongly affects the important technological and sensorial properties of goat milk (Casper et al. 1998; Siefarth and Buettner 2014).

A continuous increase in goat milk production has been registered in Serbia ever since 2010, and the domestic dairy market has been showing great interest in goat milk products (Miloradovic et al. 2015). As goat milk products, mainly cheeses, represent one of the most attractive niches in the international milk industry, evidence regarding the composition of the milk is required.

Therefore, the aim of this research was to investigate the effect of climatic conditions and their impact on seasonal variations of physico-chemical characteristics of Saanen goat milk produced in Serbia over a period of 4 years.

Materials and methods

Goat milk sampling

Milk samples were collected from a single commercial flock of ~ 250 Saanen goats during 4 years: 2012, 2013, 2014 and 2015. The goats were fed with maize silage, lucerne hay containing 14–16% of crude protein and concentrate feeds containing 14% of crude protein. There were no changes to the feeding regime throughout the lactation period. Every year, 135 samples were taken throughout the period from the beginning of March to the middle of December (45 samples per lactation period).

Physico-chemical characteristics of goat milk

Milk samples were analyzed with a Lactoscan SA60 Milkanalyzer (Milkotronic, Bulgaria) measuring the content of fat (% w/v), protein (% w/v), lactose (% w/v), non-fat dry matter (% w/v), ash (% w/v), and also density (g cm^{-3}) and freezing point (°C). Analysis of each milk sample was done in triplicate. The Lactoscan was calibrated once every 7 days.

Titrable acidity (°Soxhlet-Henkel) was determined using 0.1 M NaOH and phenolphthalein as an indicator. Milk pH was measured using a digital pH meter (Testo, Germany). Titrable acidity and pH were measured in duplicate.

Climatic condition parameters

Data regarding climatic conditions were obtained from the Meteorological Annual of the Republic Hydrometeorological Service of Serbia. Parameters used were: average monthly air temperature (°C), monthly solar radiation duration (h), and average monthly relative humidity (%). Temperature humidity index (THI) was calculated as described by Gantner et al. (2011).

Statistical analysis

Analysis of variance was used to determine the influence of lactation period (fixed factor), year (random factor) and their interaction on physico-chemical characteristics (dependent variables). Lactation periods were: early (March, April, May), mid (June, July, August) and late (September, October, November, December). Duncan's test was used to compare means of dependent variables on which lactation period had a statistically significant effect.

Pearson's coefficient of correlation was calculated between climatic condition parameters and physico-chemical characteristics.

Statistical analysis was conducted using SPSS ver. 21 (IBM Corp., Chicago, IL, USA).

Results and discussion

Physico-chemical characteristics of goat milk

All observed physico-chemical characteristics of Saanen goat milk, except density, varied significantly with seasonal changes over the year (Table 1). Significant effect of year on the same characteristics, excluding titrable acidity, was also observed. The effect of interaction of these two factors was significant for all physico-chemical

Table 1 Physico-chemical characteristics of Saanen goat milk throughout lactation periods over 4 years (mean ± standard deviation)

	Early lactation (n = 180)	Mid-lactation (n = 180)	Late lactation (n = 180)
Fat (%)	3.59 ± 0.351^{b}	2.99 ± 0.215^{c}	3.66 ± 0.399^{a}
Density (g cm^{-3})	1.0273 ± 0.00133^{a}	1.0270 ± 0.00064^{a}	1.0279 ± 0.00085^{a}
Lactose (%)	4.23 ± 0.160^{b}	4.05 ± 0.123^{c}	4.27 ± 0.150^{a}
NFDM (%)	7.70 ± 0.299^{b}	7.38 ± 0.222^{c}	7.76 ± 0.264^{a}
Proteins (%)	2.82 ± 0.111^{b}	2.70 ± 0.088^{c}	2.84 ± 0.097^{a}
pH	6.73 ± 0.064^{a}	6.72 ± 0.079^{a}	6.69 ± 0.064^{b}
Freezing point (°C)	-0.486 ± 0.0216^{b}	-0.462 ± 0.0167^{a}	-0.490 ± 0.0197^{c}
Ash (%)	0.63 ± 0.027^{b}	0.60 ± 0.021^{c}	$0.64 \pm 0.0.024^{a}$
Titrable acidity (°SH)	5.82 ± 0.385^{b}	5.80 ± 0.223^{b}	6.72 ± 0.469^{a}

Values in rows with the same letter in superscript are in homogeneous subsets

NFDM non-fat dry matter

characteristics, except pH, but percentage of variance explained by this effect was low. The highest value of partial eta squared was for density with 22.5% of variance explained. Titrable acidity had the second the highest value of partial eta squared with 12.3%. For all other physico-chemical characteristics this value was below 10%.

In mid-lactation, the main compositional parameters such as fat, protein, non-fat dry matter (NFDM) and lactose contents were significantly lower than in the early or late lactation periods. The highest variation was observed for the fat content, which was 16.7 and 18.3% lower in the mid than in the early and late lactation periods, respectively. Variation of protein, NFDM and lactose contents was less pronounced, ranging between 4.1 and 5.1% lower content in mid than in early or late lactation. Results presented in Table 2 show that the lowest values for the fat, protein, NFDM and lactose contents were in August (2.93, 2.67, 7.32 and 4.02% respectively), whereas the highest values for these compositional parameters were in December (4.09, 2.93, 7.99 and 4.40% respectively). In the review by Goetsch et al. (2011), it is reported that the lowest levels of protein and fat in goat milk were in June and July, and afterwards those levels increased until drying off in November or December. Mayer and Fiechter (2012) also observed that the levels of total solids, protein and fat in goat milk in Austria were the lowest from June to August and highest at the end of lactation in October.

A similar trend of variation in composition was also reported for cow milk, with fat content being the parameter most prone to variations during the milking season. However, the variation of goat milk composition in the present research is more pronounced than the variation reported for cow milk (Chen et al. 2014).

Regarding pH, although a statistically significant influence of lactation period on these parameters exists, the differences between early, mid and late periods were quite small (Table 1). The highest titrable acidity was observed during the late period (6.72 °SH) and is caused by higher levels of protein and ash in that period (McCarthy and Singh 2009).

The freezing point temperature of goat milk was the highest in mid-lactation (− 0.462 °C), when the protein, lactose and ash content were at their lowest levels (Table 1). Henno et al. (2008) reported similar findings for cow milk, with the possible explanation that feeding outdoors led to lower utilization of protein. However, in our study, the flock was kept indoors at all times. We consider that the higher freezing point temperature in mid-lactation was influenced by the goats' higher water intake due to higher summer air temperatures and greater solar radiation duration (SRD), which was also suggested by Bjerg et al. (2005).

Table 2 Monthly average values (mean ± standard deviation) of physico-chemical characteristics of Saanen goat milk throughout the four lactation years

	Fat (%)	Density (g cm^{-3})	Lactose (%)	NFDM[a] (%)	Protein	pH	Freezing point (°C)	Ash (%)	Titrable acidity (°SH)
March	3.92 ± 0.232	1.0277 ± 0.00050	4.33 ± 0.094	7.92 ± 0.177	2.90 ± 0.069	6.74 ± 0.048	− 0.501 ± 0.0131	0.65 ± 0.017	6.07 ± 0.229
April	3.58 ± 0.182	1.0273 ± 0.00169	4.22 ± 0.154	7.68 ± 0.276	2.81 ± 0.098	6.73 ± 0.042	− 0.483 ± 0.0182	0.63 ± 0.022	5.83 ± 0.175
May	3.32 ± 0.220	1.0272 ± 0.00137	4.14 ± 0.137	7.54 ± 0.258	2.76 ± 0.095	6.72 ± 0.033	− 0.473 ± 0.0184	0.62 ± 0.023	5.63 ± 0.062
June	3.09 ± 0.195	1.0272 ± 0.00075	4.11 ± 0.143	7.50 ± 0.298	2.75 ± 0.123	6.70 ± 0.032	− 0.469 ± 0.0205	0.61 ± 0.025	5.68 ± 0.144
July	2.97 ± 0.223	1.0269 ± 0.00040	4.02 ± 0.062	7.34 ± 0.103	2.68 ± 0.033	6.73 ± 0.050	− 0.461 ± 0.0060	0.60 ± 0.012	5.79 ± 0.033
August	2.93 ± 0.149	1.0268 ± 0.00045	4.02 ± 0.066	7.32 ± 0.127	2.67 ± 0.044	6.74 ± 0.069	− 0.458 ± 0.0087	0.59 ± 0.010	5.90 ± 0.099
September	3.17 ± 0.039	1.0272 ± 0.00055	4.08 ± 0.093	7.44 ± 0.177	2.72 ± 0.064	6.72 ± 0.023	− 0.467 ± 0.0102	0.61 ± 0.018	6.19 ± 0.240
October	3.43 ± 0.167	1.0279 ± 0.00077	4.25 ± 0.098	7.74 ± 0.178	2.83 ± 0.064	6.70 ± 0.049	− 0.487 ± 0.0095	0.63 ± 0.013	6.71 ± 0.299
November	3.81 ± 0.159	1.0280 ± 0.00025	4.30 ± 0.056	7.80 ± 0.127	2.85 ± 0.045	6.67 ± 0.029	− 0.495 ± 0.0099	0.64 ± 0.014	6.92 ± 0.438
December	4.09 ± 0.210	1.0282 ± 0.00033	4.40 ± 0.087	7.99 ± 0.159	2.93 ± 0.060	6.68 ± 0.068	− 0.509 ± 0.0125	0.66 ± 0.017	6.93 ± 0.222

[a] *NFDM* non-fat dry matter

Relationship between climatic condition parameters and physico-chemical characteristics of goat milk

Climatic condition parameters measured from March to December of 2012–2015 are presented in Table 3.

High air temperatures have a negative effect on dairy cow environment (Brouček et al. 2006; Sharma et al. 1983). Our study confirms the same negative effect was observed for Saanen goats, with a statistically significant negative correlation between air temperature and the main physico-chemical characteristics of the milk (Table 4). The most highly affected characteristic by the air temperature was fat content with the correlation coefficient of − 0.90. The least affected characteristic was density with correlation coefficient of − 0.46. The pH value was not affected by air temperature.

Our results also showed that the second important parameter that negatively affected goat milk physico-chemical characteristics was SRD. All physico-chemical parameters, except density, were significantly correlated with SRD (Table 4). Fat content was again the most highly affected characteristic with correlation coefficient of − 0.79, and the least affected was pH with correlation coefficient of 0.41. Air temperature and SRD combined, resulted in the animals having a high water intake, which further affects overall milk quality (Bjerg et al. 2005; Chen et al. 2014), as discussed earlier. To the best of our knowledge, no study has reported the correlation between SRD and milk composition, to date.

Although Rodriquez et al. (1985) reported that relative humidity influenced the variability of the basic composition of cow milk, in our study, only the fat content, pH and titrable acidity of goat milk were significantly correlated with relative humidity with correlation coefficients being below 0.70 for all three characteristics (Table 4).

THI was significantly correlated with all physico-chemical characteristics except pH. The highest coefficient was for fat content (− 0.93) and the lowest was for density (− 0.40) (Table 4). Observing the THI throughout the lactation period (Table 3), it was clear that all values were

Table 3 Monthly average values of climatic parameters throughout the four lactation years (means of monthly average values over four lactation years ± standard deviation)

	Air temperature (°C)	Relative humidity (%)	SRD[a] (h)	THI[b]
March	7.50 ± 1.347	70.0 ± 10.44	186.47 ± 63.256	47.71 ± 2.765
April	12.65 ± 0.507	70.0 ± 4.58	195.83 ± 41.360	55.64 ± 0.214
May	17.20 ± 0.868	71.3 ± 2.52	228.33 ± 15.958	61.61 ± 0.989
June	20.92 ± 1.217	69.3 ± 5.03	277.30 ± 36.806	67.70 ± 1.855
July	23.15 ± 1.611	67.3 ± 9.02	316.53 ± 41.003	70.21 ± 1.877
August	22.62 ± 1.389	63.7 ± 12.50	311.83 ± 52.901	69.25 ± 1.456
September	17.75 ± 1.578	71.0 ± 10.00	182.33 ± 39.847	62.49 ± 2.467
October	12.80 ± 0.942	77.0 ± 1.73	166.70 ± 10.941	56.06 ± 0.705
November	8.22 ± 0.936	82.0 ± 1.73	93.60 ± 5.864	48.61 ± 0.706
December	1.97 ± 1.350	87.0 ± 2.00	65.97 ± 16.426	36.54 ± 2.217

[a]*SRD* solar radiation duration

[b]*THI* temperature humidity index

Table 4 Pearson's coefficients of correlation between physico-chemical characteristics and climatic parameters

	Fat	Density	Lactose	NFDM[a]	Proteins	pH	Freezing point	Ash	Titrable acidity
Air temperature	− 0.90*	− 0.46*	− 0.77*	− 0.74*	− 0.74*	0.30	0.78*	− 0.75*	− 0.70*
Relative humidity	0.56*	0.07	0.27	0.22	0.22	− 0.67*	− 0.29	0.22	0.64*
SRD[b]	− 0.79*	− 0.31	− 0.57*	− 0.52*	− 0.51*	0.41*	− 0.57*	− 0.53*	− 0.76*
THI[c]	− 0.93*	− 0.40*	− 0.76*	− 0.72*	− 0.72*	0.23	− 0.76*	− 0.73*	− 0.69*

Values flagged with an (*) are statistically significant, $p < 0.05$

[a]*NFDM* non-fat dry matter

[b]*SRD* solar radiation duration

[c]*THI* temperature humidity index

below 72, which was considered as a critical point at which heat stress appeared for dairy cows (Gantner et al. 2011). Also, for dairy cows, an increase of THI to within the range of 71–81 results in a decrease of feed intake and increase of water intake. In our study, the high correlation between THI and most of physico-chemical characteristics of Saanen goat milk was confirmed (Table 4). As mentioned earlier, the mid-lactation period was characterized by great decreases of important physico-chemical parameters, especially fat content. During our study it was not possible to accurately measure the feed and water intake, so we can only make an educated guess that heat stress in Saanen goats appeared at lower levels of THI than it does in dairy cows, and we speculate that the critical value of THI may be 67, which is around the lowest average value we recorded in mid-lactation.

Earlier research on seasonal variations of goat milk composition, by Mayer and Fiechter (2012), showed that the average basic composition of Saanen goat milk in Austria was considerably higher than that of milk from the Saanen goat flock examined in this study. The flock used in this study was from Austria. Based on these facts and the high correlation between climatic conditions and the basic composition of goat milk in our study, we assumed that Saanen goats were very prone to being affected by the adverse climatic conditions which were experienced by them during hot summers.

Conclusion

In our study, the decrease in all the basic parameters of milk composition (fat, proteins, lactose, NFDM, ash) during the mid-lactation period was more pronounced than reported in the literature to date. The reason could be found in the high negative correlation that physico-chemical characteristics have with the THI, SRD and air temperature. This observation leads to a conclusion that Saanen goats are very prone to heat stress, which could strongly affect the expected quality of goat milk products throughout the year. Further investigations should aim at determining the critical value of THI that affects the overall quality of raw Saanen goat milk and products.

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References

Bjerg M, Rasmussen MD, Nielsen MO (2005) Changes in the freezing point of blood and milk during dehydration and rehydration of lactating cows. J Dairy Sci 88:3174–3185

Broučel J, Mihina Š, Ryba Š, Tongel P, Kišac P, Uhrinčat M, Hanus A (2006) Effects of high air temperatures on milk efficiency in dairy cows. Czech J Anim Sci 51:93–101

Casper JL, Wendorff WL, Thomas DL (1998) Seasonal changes in protein composition of whey from commercial manufacture of caprine and ovine specialty cheeses. J Dairy Sci 81:3117–3122

Chen B, Lewis MJ, Grandison AS (2014) Effect of seasonal variation on the composition and properties of raw milk destined for processing in the UK. Food Chem 158:216–223

Faye B, Konuspayeva G (2012) The sustainability challenge to the dairy sector—the growing importance of non-cattle milk production worldwide. Int Dairy J 24:50–56

Gantner V, Mijić P, Kuterovac K, Solić D, Gantner R (2011) Temperature-humidity index values and their significance on the daily production of dairy cattle. Mljekarstvo 61:56–63

Goetsch AL, Zeng SS, Gipson TA (2011) Factors affecting goat milk production and quality. Small Ruminant Res 101:55–63

Henno M, Ots M, Jõudu I, Kaart T, Kärt O (2008) Factors affecting the freezing point stability of milk from individual cows. Int Dairy J 18:210–215

Jensen RG, Ferris AM, Lammi-Keefe CJ (1991) The composition of milk fat. J Dairy Sci 74:3228–3243

Lindmark-Månsson H, Fondén R, Pettersson H-E (2003) Composition of Swedish dairy milk. Int Dairy J 13:409–425

Mayer KH, Fiechter G (2012) Physicochemical characteristics of goat's milk in Austria–seasonal variations and differences between six breeds. Dairy Sci. Technol 92:167–177

McCarthy OJ, Singh H (2009) Physico-chemical properties of milk. In: McSweeney P, Fox PF (eds) Advanced dairy chemistry volume 3: lactose, water, salts and minor constituents, 3rd edn. Springer, New York, pp 691–758

Milani M, Hense A, Rahmani E, Ploeger A (2015) A pilot investigation of the relationship between climate variability and milk compounds under the bootstrap technique. Foods 4:420

Miloradovic ZN, Kljajevic NV, Jovanovic ST, Vucic TR, Macej OD (2015) The effect of heat treatment and skimming on precipitate formation in caprine and bovine milks. J Dairy Res 82:22–28

Ng-Kwai-Hang KF, Hayes JF, Moxley JE, Monardes HG (1985) Percentages of protein and nonprotein nitrogen with varying fat and somatic cells in bovine milk. J Dairy Sci 68:1257–1262

Poulsen NA, Rybicka I, Poulsen HD, Larsen LB, Andersen KK, Larsen MK (2015) Seasonal variation in content of riboflavin and major minerals in bulk milk from three Danish dairies. Int Dairy J 42:6–11

Rodriquez LA, Mekonnen G, Wilcox CJ, Martin FG, Krienke WA (1985) Effects of relative humidity, maximum and minimum temperature, pregnancy, and stage of lactation on milk composition and yield1. J Dairy Sci 68:973–978

Sharma AK, Rodriguez LA, Mekonnen G, Wilcox CJ, Bachman KC, Collier RJ (1983) Climatological and genetic effects on milk composition and yield1. J Dairy Sci 66:119–126

Siefarth C, Buettner A (2014) The aroma of goat milk: seasonal effects and changes through heat treatment. J Agric Food Chem 62:11805–11817