

Relationship of milking traits and somatic cell count with electrical conductivity of goat milk during different milking phases

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Abstract

The aim of this study was to estimate the relation between milking traits and somatic cell count with electrical conductivity of goat milk during different milking phases. The research was carried out in the herd of Czech White Shorthaired and Saanen goat breeds (n=323) with the help of the electronic milk flow meter LactoCorder®. The milk yield, milking duration, milking flow rate and electrical conductivity of milk in the different phases of milking showed the significant mean differences between the breeds. Almost all (except electrical conductivity during the initial time) investigated indicators of electrical conductivity had a significant positive correlation with SCC. The bimodality of milk flow was determined in 9.69 % of goats and associated with milk yield decrease and SCC increase (P<0.05). The results confirm that the milk flow curve data is a good tool to control milking traits of goats, to predict the prevalence of mastitis and, thus, to improve the health of the udder of goats.

Key words: goat, electrical conductivity, bimodality, milk flow curve

Introduction

Goat milk production is a growing industry (Gautam et al., 2020) and is used to make products such as cheese or yoghurt, therefore it is essential to have high quality milk in order to produce quality products (Silanikove et al., 2010; Romero et al., 2012; Zazharska et al., 2018). There is an increasing demand for high quality goat milk, however, there is also one of the major problems - mastitis. It affects not only goat productivity and health but also the welfare of the animal. Mastitis in all its forms is the major factor that affects the impact of raw milk quality on finished dairy product quality and economic losses (Leitner et al., 2008; Romero et al., 2012). Intramammary infection is related to the increase in the somatic cell count in small ruminants (Zaninelli et al., 2015).

Somatic cell count and electrical conductivity are used in the diagnosis of mastitis (Morgante et al., 2000; Paape, 2000). Normal goat milk has a higher somatic cell count (700 000 to 1 000 000 cells/mL) than cow milk (Hinckley and Williams, 1981). Investigation of Yarabbi et al. (2014) in dairy cows showed that increase in the somatic cell count was associated with an increase of electrical conductivity ($P < 0.05$). Tangorra et al. (2010) found a significantly higher level of electrical conductivity in infected glands in different lactation stages.

The prevalence of mastitis in the goat population is influenced by genetic and non-genetic factors. Proper application and use of milking techniques on dairy goat farms can reduce the incidence of this disease. Milk yield and milk flow are important parameters, which should be evaluated and registered in goats (Borghese et al., 2013; Amin, 2020). Breed of dairy goats has an effect on milk yield (Guney et al., 2006; Norris et al., 2011). Kendall et al. (2009) estimated that the level of milk production depends on a breed, and there is variation in milk yield among different breeds and within the breed. Ying et al. (2004), in a study carried out with different breeds of goats, reported contradictory results: EC increased with infection in Saanen but decreased in Alpine goats. Diaz et al. (2011) estimated a significant correlation between electrical conductivity and milk yield in infected glands; analysing the data separately according to the health status of glands, the correlation was significant for

infected glands, but no significant relations were estimated for other mastitis-free glands.

Therefore, early detection of mastitis should be an important management tool in goat farms (Romero et al., 2012; Zaninelli et al., 2015). However, estimation of electrical conductivity of goat milk is not broadly covered in the literature (Tangorra et al., 2010; Diaz et al., 2012). Since a reliable increase in electrical conductivity is established in milk of cows with mastitis, it must be possible to apply this indicator to establish mastitis in goats (Diaz et al., 2012).

Analysis of scientific literature has shown that there is a lack of data on goat milk flow rates at different phases of milking. The choice of publications on establishing electrical conductivity of goat milk is not very wide (Romero et al., 2012; Diaz et al., 2012). Moreover, there was no literature available on determining electrical conductivity of goat milk during different milking phases. The aim of this study was to estimate a relation between milking traits and somatic cell count with electrical conductivity of goat milk during different milking phases.

Materials and methods

The research was carried out in the herd of two goat breeds (Czech White Shorthaired, $n=230$, and Saanen, $n=93$) in Lithuania, at the State Enterprise Laboratory for Milk Control 'Pieno Tyrimai' and at the Department of Animal Breeding and Nutrition of Lithuanian University of Health Sciences. All investigated goats were raised in the same feeding and housing conditions. The animals were milked twice a day (7:00 a.m. and 6:00 p.m.). Milking parlor had a low-line design, self-locking gates and 2 platforms with 8 milking units and milking posts per platform. Milking parameters: a pulsation rate of 90 cycles/min, a vacuum level of 40 kPa and a pulsation ratio of 60 %.

The 323 goats with lactation period of 2-4 months, on average of 3.3 ± 0.09 lactation were evaluated three times with the help of the electronic milk flow meter LactoCorder® (Lactocorder® WMB AG, Switzerland). LactoCorder® has been recognized as a measurement device by ICAR (International Committee for Animal Recording). The results of our measurements with LactoCorder®

(<http://www.lactocorder.ch>) were processed by the software program pack LactoPro 5.2.0 (Biomelktechnik Swiss). A general description of investigated traits evaluated using LactoPro 5.2.0 program in this research:

- / **MGG** - Total milk yield (from the beginning to the end of the measurement), kg;
- / **Milking duration parameters**
- / tMGG - Duration of the total milking, min;
- / tMHG - Duration of the main milking phase, min;
- / **Milking flow rate parameters**
- / HMF - Highest milk flow rate in one minute, kg/min;
- / DMHG - Average milk flow in the main milking phase, kg/min.
- / **Electrical conductivity parameters**
- / ELHMF - electrical conductivity at highest milk flow (mS/cm),
- / ELAP - electrical conductivity during the initial time (mS/cm) of milking (beginning peak level of the electrical conductivity),
- / ELAD - beginning peak difference of the electrical conductivity (mS/cm),
- / ELMAX - maximum electrical conductivity after reaching the highest milking speed (mS/cm),
- / ELST - step in the electrical conductivity (mS/cm),
- / ELND - level difference of the electrical conductivity (mS/cm),
- / ELMNG - maximum electrical conductivity after main milking (mS/cm),

Bimodality of milk flow (BIMO) was detected when a curve had a flow pattern with 2 increments separated by a clear drop in milk flow for more than 200 g/min within 1 min after the start of milking (Dzidic et al., 2004). Bimodality of milk flow was observed when it was repeated at least two milking's.

The research on the somatic cell count (SCC) in milk samples was performed at the State Enterprise Pieno Tyrimai. SCC in milk was determined using the measuring device Somascope (CA-3A4, 2004; Delta Instruments, the Netherlands), which operates on the principle of flow cytometry technology. State Enterprise Pieno Tyrimai operates under the quality management system conforming to the requirements of International Standard ISO/IEC 17025:2005 to ensure the accuracy of milk composition and quality tests.

Statistical characteristics in the sample (n) - arithmetic mean (M), standard error (SE), P - value (P) - were calculated using IBM SPSS Statistics, version 20. Values SCC ($\times 1000$ cells/mL) were transformed into base 10 logarithm to normalize their distribution. Data analysis was performed by using Student's t test. The relationship among the milking traits and SCC was determined using Pearson's correlation coefficient (r). The results were considered statistically significant when $P \leq 0.05$.

The research was conducted following the provisions of the Republic of Lithuania Law on the Care, Keeping and Use of Animals No 11-2271 of 03/10/2012 (Valstybės žinios (Official Gazette) 11010112 No 122- 6126 dated 20/10/2012) and other legal acts, and the Requirements for the keeping, care and use of animals used for scientific and training purposes No B1-866, dated 31/10/2012 (Valstybės žinios No 130-6595 dated 10/11/2012).

Results and discussion

The means and standard errors of total milk yield (MGG), total milking duration (tMGG), average milk flow in the main milking phase (DMHG), electrical conductivity at highest milk flow (ELHMF) and somatic cell count (SCC) in dairy goats used in this study were 1.511 ± 0.045 kg, 2.965 ± 0.099 min, 0.634 ± 0.014 kg/min, 7.046 ± 0.044 mS/cm and 6.123 ± 0.032 , respectively.

Different goat breeds milk yield, milking duration and milking flow rate parameters are presented in Table 1. The Czech White Shorthaired breed showed on average a 0.217 kg higher total MGG per milking than Saanen breed ($P=0.023$). By comparison with our results, Ciappesoni et al. (2004) reported similar Czech White Shorthaired goat breed milk production (3.09 kg/day). Boselli et al. (2009) reported means of milk yield per milking in Saanen goat breed from 1.63 ± 0.04 kg (early lactation) to 0.67 ± 0.05 kg (late lactation). Mioč et al. (2008) found that the Saanen breed had significantly ($P < 0.01$) higher lactation and daily milk yield than the Alpine breed (720 kg and 2.63 kg/day versus 577 kg and 2.08 kg/day, respectively). Conversely, Palhière et al. (2014) estimated a slight influence of the breed from 1012 ± 212 kg (Alpine breed) to 994 ± 237 kg (Saanen breed) per lactation.

TABLE 1. Milk yield and milking traits in Czech White Shorthaired and Saanen dairy goats

Parameters	Czech White Shorthaired	Saanen	P
MGG, kg	1.555±0.053	1.338±0.078	0.023
tMGG, min	3.156±0.115	2.218±0.142	<0.001
tMHG, min	2.590±0.109	1.800±0.097	<0.001
HMF, kg/min	0.857±0.019	0.943±0.037	0.040
DMHG, kg/min	0.617±0.014	0.703±0.035	0.024

TABLE 2. Electrical conductivity of milk from Czech White Shorthaired and Saanen dairy goats in different milking phases

Parameters	Czech White Shorthaired	Saanen	P
ELAP	7.236±0.106	6.967±0.319	0.425
ELAD	0.298±0.029	0.226±0.028	0.077
ELMAX	7.513±0.050	7.656±0.089	0.013
ELMNG	3.880±0.203	2.939±0.460	0.050
ELHMF	6.955±0.049	7.402±0.086	<0.001
ELST	0.731±0.067	0.436±0.075	0.003
ELND	1.059±0.073	0.692±0.094	0.002

The duration of the total milking (tMGG) and the duration of the main milking phase (tMHG) were also significantly higher ($P<0.001$) in Czech White Shorthaired breed in comparison to the Saanen breed (0.938 min and 0.79 min, respectively). Meanwhile the milking flow rate parameters were as follows: average milk flow in the main milking phase (DMHG) and maximum milk flow rate in one minute (HMF) were significantly higher in Saanen breed as compared to Czech White Shorthaired breed 0.086 kg/min ($P=0.024$) and 0.086 kg/min ($P=0.040$), respectively. In comparison to our results, French scientists Palhière et al. (2014) have determined higher milking speed traits in the Alpine breed compared to the Saanen breed. In the course of the same research, the average milk flow during the main milking phase and the maximum milk flow per minute was 0.09 kg/min and 0.12 kg/min higher in Alpine breed, respectively. Boselli et al. (2009) reported higher means of maximum milk flow per minute in Saanen goat breed from 1.41 ± 0.05 kg/min (early lactation) to 0.92 ± 0.05 kg/min (late lactation) ($P<0.001$). Ilahi et al. (2000) noted the average milking speed of 1.095 kg/min in Alpine

goat breed. Bašić et al. (2009) determined higher means of total milking time from 2.48 ± 0.10 kg/min (third lactation) to 1.61 ± 0.10 kg/min (fourth lactation) ($P<0.05$) in the Alpine goats. The Spanish scientists Fernández et al. (2019) determined that by increasing the vacuum level from 42 to 44 kPa milk flow significantly increased and the total milking time decreased by 25 seconds in Murciano-Granadina breed goats ($P<0.05$). Zucali et al. (2019) examined the duration of the main milking phase in the Alpine goat breed and found that the highest values of peak flow and average milk flow were significantly affected by the vacuum level ($P<0.001$).

The different goat breed averages of electrical conductivity are demonstrated in Table 2. The higher ELAP, ELAD, ELST, ELND, ELMNG were determined in Czech White Shorthaired breed (from 3.86 % ELAP to 67.66 % ELST). Meanwhile, ELMAX and ELHMF were significantly higher ($P<0.01$) in the Saanen goat breed at 1.9 % and 6.43 %, respectively. The effects of health condition, farm, lactation and stage of lactation are associated with EC (Diaz et al., 2011; Romero et al., 2012). The studies of Ying et al. (2004) in two breeds of goats

demonstrated that the electrical conductivity in the Saanen breed of goats increased by 3.5 %, while in the Alpine goats this indicator decreased by 11.5 % when comparing the milk of healthy goats and goats infected with mastitis. Romero et al. (2012) studied the Murciano-Granadina goats and determined 28.72 % of EC as compared to our results. They reported 5.31 mS/cm mean of EC (from 5.07 mS/cm in primiparous goats to 5.45 mS/cm in multiparous goats ($P<0.001$)).

For Czech White Shorthaired goats SCC had a significant positive correlation with almost all (except ELAP) investigated indicators of electrical conductivity (Table 3). For the Saanen breed, these correlations were equally reliable and higher (from 0.223 with ELAD to 0.406 with ELHMF). Similar results were reported by Diaz et al. (2012) determining a significant, moderate correlation between EC and SCC ($r = 0.38$, $P<0.001$) in the study with Murciano-Granadina goats. In the meantime, Ying et al. (2004) reported a lower correlation coefficient between electrical conductivity and SCC (0.089 and 0.056 in Saanen and Alpine goats, respectively).

Between milk yield and milking duration MGG had the highest repeatability value with tMHG (0.636-0.760, respectively in Saanen and in Czech White Shorthaired goats), and the following value was tMGG (0.501-0.721 respectively in Saanen and in Czech White Shorthaired goats). Repeatability of MGG and milking flow rate parameters were lower than in the previous ones (0.165 and 0.184, respectively with HMF and DMFG in Czech White Shorthaired goats and 0.433-0.468 in Saanen goats). Phenotypic correlations of tMGG with tMHG and HMF with DMHG were very high and positive for both breeds ($P<0.01$). By comparison with our results, Peris et al. (1999) reported that milk yield correlated with milking time ($r=0.69$; $P<0.005$ in Murciano-Granadina goats) and Ilahi et al. (1999) determined correlations between the daily milk production and maximum flow rate ($r=0.42$ in Alpine goat breed).

Assessing the relationship between the indicators of electrical conductivity of milk, the strongest correlation coefficients were estimated between ELMAX and ELHMF (0.892 and 0.933, respectively in Czech White Shorthaired and in Saanen goats). Very high and positive correlations between ELST

TABLE 3. Correlation coefficients among milk yield, milking duration, milking flow rate, electrical conductivity and SCC in Czech White Shorthaired (horizontal line) and in Saanen (vertical line) dairy goats

	SCClog10	MGG	tMGG	tMHG	HMF	DMHG	ELAP	ELAD	ELMAX	ELMNG	ELHMF	ELST	ELND
SCClog10	1	0.192**	0.162**	0.118*	0.092	0.118*	0.093	0.142*	0.267**	0.279**	0.290**	0.270**	0.248**
MGG	0.079	1	0.725**	0.760**	0.184**	0.165**	0.085	-0.031	0.136*	-0.039	-0.003	0.097	0.143*
tMGG	0.061	0.501**	1	0.916**	0.081	-0.370**	0.006	-0.148	0.081	0.108	-0.021	0.108	0.209**
tMHG	-0.008	0.636**	0.903**	1	-0.268**	-0.392**	0.051	-0.143*	0.124*	-0.075	0.022	0.020	0.150**
HMF	0.129	0.433**	-0.460**	-0.464**	1	0.878**	0.162**	0.050	-0.015	0.064	0.097	-0.003	-0.125*
DMHG	0.081	0.468**	-0.489**	-0.524**	0.909**	1	0.120	0.028	-0.028	0.090	0.038	-0.030	-0.136*
ELAP	0.237**	0.140*	0.045	0.017	0.123	-0.036	1	0.196**	0.401**	-0.137*	0.403**	-0.014	-0.011
ELAD	0.223**	0.015	0.153*	-0.002	-0.036	-0.026	0.332**	1	-0.430**	-0.075	-0.290**	-0.072	-0.129
ELMAX	0.321**	0.043	-0.148**	-0.145*	-0.104	-0.139*	0.403**	0.009	1	-0.075	0.892**	0.129	0.185*
ELMNG	0.308**	0.100	0.506**	0.225**	-0.152*	-0.172**	0.001	0.299**	0.078	1	-0.041	0.121	0.079
ELHMF	0.406**	0.133*	-0.183*	-0.170*	-0.002	-0.057	0.385**	-0.001	0.933**	0.108	1	0.073	0.088
ELST	0.314**	0.320**	-0.055	-0.108	0.429**	0.180*	0.226**	0.114*	0.177*	0.248**	0.267**	1	0.882**
ELND	0.400**	0.316**	0.209**	0.158**	0.125	-0.102	0.369**	0.084	0.218**	0.297**	0.231**	0.741*	1

* $P<0.05$; ** $P<0.01$

TABLE 4. Effect of bimodality of milk flow curve in Czech White Shorthaired dairy goats

Breed	Bimodality of milk flow curves	MGG		SCC	
		M	SE	M	SE
Czech White Shorthaired	Normal curve	1.586*	0.0058	6.175*	0.034
	Bimodal curve	1.298	0.116	6.208	0.118
Saanen	Normal curve	1.460*	0.101	6.002*	0.072
	Bimodal curve	1.329	0.083	6.083	0.061

* $P < 0.05$

and ELND, while moderate positive correlations between ELMAX and ELAP were estimated in both breeds. There were differences in the results of correlation analysis of electrical conductivity parameters between Czech White Shorthaired and Saanen goats. Czech White Shorthaired goats had moderate significant positive correlations between ELAD and ELMAX, ELAP and ELHMF ($P < 0.01$) which were not determined in Saanen goats. Saanen goats had a significant positive ELAP correlation between ELAD and ELND (0.332 and 0.369, respectively) which was not the case in Czech White Shorthaired goats.

In the present study, the bimodality of milk flow (Table 4) was determined in 9.69 % goats (10.43 % in Czech White Shorthaired goat breed and in 6.78 % in Saanen goat breed, $P < 0.01$). Boselli et al. (2016) reported higher results of bimodality (17.7 %). In study, comprising 3 goat breeds (Alpine, Maltese and Saanen), they reported the bimodality of 20.45 %, 18.81 % and 14.07 %, respectively. On contrary, Zucali et al. (2019) estimated that the frequency of bimodal curves was very low (0.83 % on average) in the Alpine goat breed. We determined that MGG was higher ($P < 0.01$) in normal milk flow curve from 0.131 kg (Saanen goat breed) to 0.288 kg (Czech White Shorthaired goat breed) compared to bimodal milk flow curve. In the present study a slight but significant ($P < 0.01$) SCC increase was indicated (0.033-0.081) in goats with bimodal milk flow curve. No bibliographic references were found in respect to the goats. In case of cows, Samoré et al. (2011) observed a 10.11 % lower milk yield and 4.12 % higher SCC in cows with bimodal milk flow curve compared to normal milk flow curve.

Conclusions

The present study investigated the parameters for milk yield, milking duration, milking flow rate, electrical conductivity and SCC in Czech White Shorthaired and Saanen goats. The analysis of the parameters showed the significant mean differences between the breeds ($P < 0.05$). Phenotypic correlations of MGG with tMHG and tMGG were high, meanwhile those of tMGG with tMHG and HMF with DMHG were very high and positive for both breeds ($P < 0.01$). The significant positive SCC correlation with almost all (except ELAP) investigated indicators of electrical conductivity suggest that it should be also one of the diagnostic methods for mastitis detection. Electrical conductivity equipment during milking may improve mastitis detection and thus improve udder health of goats.

Our findings indicated that bimodality in milk flow of goats is associated with milk yield decrease and SCC log 10 increase ($P < 0.05$), and supports the hypothesis of the unprofitable effect of bimodality on goat health and should be avoided during milking.

Povezanost muznih karakteristika i broja somatskih stanica s električnom provodljivošću kozjeg mlijeka tijekom različitih faza mužnje

Sažetak

Cilj ove studije bio je procijeniti odnos muznih karakteristika i broja somatskih stanica (SCC) s električnom provodljivošću kozjeg mlijeka tijekom različitih faza mužnje. Istraživanje je provedeno u stadiu pasmina češka bijela kratkodlaka i sanska koza (n=323) uz pomoć elektroničkog mjerača protoka mlijeka LactoCorder®. Količina mlijeka, trajanje mužnje, brzina protoka pri mužnji i električna provodljivost mlijeka u različitim fazama mužnje pokazali su značajne razlike između pasmina. Gotovo svi (osim ELAP) ispitivani pokazatelji električne provodljivosti pokazali su značajnu pozitivnu povezanost s brojem somatskih stanica. Bimodalnost protoka mlijeka utvrđena je kod 9,69 % koza i povezana je sa smanjenjem prinosa mlijeka i porastom broja somatskih stanica ($P < 0,05$). Rezultati potvrđuju da su podaci krivulje protoka mlijeka dobar alat za kontrolu muznih karakteristika, za predviđanje prevalencije mastitisa te tako za poboljšanje zdravlja vimena koza.

Ključne riječi: koza, električna vodljivost, bimodalnost, krivulja protoka mlijeka

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