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Evaluation of size distribution of fat globules and fat and protein content in Estonian Goat milk

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Abstract. The objectives of this study were to investigate size distribution of fat globules, fat and protein content in Estonian goat milk. The bulk milk samples were collected from three different crossbreed goat herds. These herds consist of 30% of the Saanen breed and 70% did not belong to any certain breed. Lactation of goats was scattered over the year. Goat milk samples were examined weekly during a 10 month period. Fat and protein content in goat milk ranged from 3.09% to 5.04% and from 2.74% to 3.96% respectively. Fat content in cow milk ranged from 3.77% to 4.75% and protein content ranged from 3.14% to 3.75%. The average fat content in goat milk (3.88%) was less than the mean fat content in cow milk (4.0%). The average protein content in goat milk (3.41%) was higher than the mean protein content in cow milk (3.38%). Depending on the season, fat and protein content in goat milk varied by as much as 0.38% and 0.28% accordingly. The diameter of milk fat globules (MFG) was estimated using microscope Nikon SMZ 1000, equipped with the digital camera Nikon DS-U2/L2 USB and the software NIS-Elements D3.1. The average diameter of fat globules was 2.22 µm, ranging from 0.34 to 6.99 µm. The average size distribution of MFG had unimodal and slightly right skewed shape: 5.7% of globules were in range 0.5–1.0 µm, 15.9% in range 1.0–1.5 µm, 22.1% in range 1.5–2.0 µm, 21.0% in range 2.0–2.5, 16.1% in range 2.5–3.0 µm, 10.0% in range 3.0–3.5 µm, 4.3% in range 3.5–4.0 µm, 0.9% in range 4.5–5.0 µm.

Key words: goat milk, fat, protein, fat globules size distribution.

INTRODUCTION

The percentage of goat milk in total milk consumption has significantly increased during recent decades in Estonia. Therefore, more in-depth knowledge about the composition and properties of it is needed, especially in context of dairy production (Haenlein. 2004; Sanz Ceballos et al., 2009).

According to studies, carried out in different countries, fat content in goat milk ranges from 2.75% (Jandal, 1996) to 5.23% (Sanz Ceballos et al., 2009) and protein content from 2.98% to 3.66% (Strzałkowska et al., 2009) in average. Fat and protein content of goat milk depends on feeding, breed, individuals, parity, season, management, environmental conditions, locality, stage of lactation and health status of the udder (Park et al., 2007; Rewati Raman Bhattarai, 2012).

Depending on the stage of lactation and goat breeds, an average content of casein in goat milk varies from 1.06–3.01g $100g^{-1}$, lactose content from 3.85–5.46 g $100g^{-1}$, total solids from 9.8–15.9 g $100g^{-1}$ (Salem et al., 2004; Strzałkowski et al., 2009). The average pH in goat milk ranges from 6.6–6.9 (Salem et al., 2004), density from 1025.7–1029.8 g L^{-1} (Strzałkowski et al., 2009). Microstructure of goat milk has been studied less although the size of milk fat globules (MFG) significantly affects the valorisation of milk (Sanz Ceballos et al., 2009), especially into fat-rich products. Size of MFG has an important impact on the smoothness or hardness of cheese also (Park et al., 2007).

While goat milk has been investigated quite profoundly in many countries (Pisanu et al., 2013; Attaie and Richtert, 2000; Strzałkowska et al., 2009), no information about the content and microstructure of it can be found concerning Estonia. The aim of current research was to study the size distribution of MFG, fat and protein content in Estonian goat milk.

MATERIALS AND METHODS

The bulk milk samples were collected weekly from three Estonian goat herds during 10 months. Samples were cooled down and stored at 5°C after milking and all analyses where performed in the same day. Milk fat content and the size distribution of MFG were analysed in Estonian University of Life Sciences, Department of Food Science and Technology.

For estimation of the particle size in milk indirect methods basing on dynamic light scattering (DLS) and laser light scattering (LLS) have been used mainly (Attaie & Richtert, 2000; Michalski et al., 2003; Mootse et al., 2014; Sats et al., 2014). Results of these reflect the hydrodynamic diameter of particles which differs from real size to a certain extent. Fat globules can be measured directly also using light microscopy. In our experiments MFG size distribution was examined by the Microscope Nikon SMZ 1000, equipped with the Digital Camera (DC) Nikon DS-U2/L2 USB. For image processing software NIS-Elements D3.1 was used.

To estimate MFG size distribution, 10 µl of goat milk was diluted in 2 ml of distilled water. Diluted milk (1:200) was inserted into a 0.004 µl volume chamber and 40 times enlarged images of it were recorded under the microscope by the digital camera DC. Photographing was carried out with three different focusing depths on the volume chamber (Fig. 1). The diameter of fat globules was determined from these pictures later on.

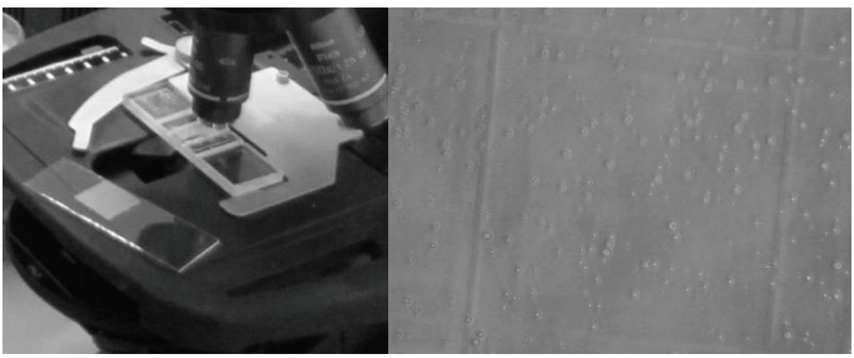

Figure 1. Photographing a unit volume chamber with Microscope Nikon SMZ 1000.

MFG size of individual milk samples was described by average, standard deviation, minimum and maximum values. To derive size distribution of MFG, the results were grouped into 0.5 μm range groups and tabulated accordingly (cf. Table 2).

Protein content was estimated in Estonian Animal Recording Centre with Analysers (FOSS Electric, Denmark), using international standard methods. Milk fat content was estimated by the standard Gerber method. For comparative analysis the average fat and protein content of Estonian cow milk estimated in Estonian Animal Recording Centre was used.

Data were analysed and according illustrations were constructed using statistical package R and MS Excel.

RESULTS AND DISCUSSION

Fat content of the studied goat milk varied from 3.09% to 5.04%. An average fat content was 3.88% (Table 1), which is somewhat higher than in a study conducted in the US (Park et al., 2007). Protein content of Estonian goat milk ranged between 2.74% and 3.96%. The average protein content was 3.41%, which is similar to references in literature (Park et al., 2007). Differences in the results can be attributed to regional peculiarities, breeding conditions, feeding, etc. (Salem et al., 2004; Park et al., 2007; Sanz Ceballos et al., 2009; Rewati Raman Bhattarai, 2012;). Comparing average fat and protein content in Estonian goat milk with corresponding parameters of cow milk in Estonia, it turned out that the average fat content in goat milk was a bit lower and average protein content a little higher than that in cow milk.

Table 1. Ranges in level, average fat and protein content, standard errors (SE) of goat and cow* milk

Component, %	Ranges in level, % goat (cow)	Average, % goat (cow)	SE goat (cow)
Fat	3.09–5.04 (3.77–4.75)	3.88 (4.00)	0.46 (0.23)
Protein	2.74–3.96 (3.14–3.75)	3.41 (3.38)	0.27 (0.43)

* Estonian Animal Recording Centre, 2013.

Seasonal variation existed in the fat and protein content (Fig. 2). The lowest average fat and protein content (3.65%, 3.22%) was during spring-summer season, between April and June. The highest average fat and protein content were in October-December and in July-September accordingly.

The average diameter of Estonian goat MFG size was 2.22 μm, ranging from 0.34 μm to 6.99 μm. This range exceeded results presented by El-Zeini (2006) who investigated MFG size in the buffalo, sheep, cow, camel and goat milk. His study showed that the size of buffalo fat globules was in between 0.1–4.0 μm which was less than that of sheep (by 55.3%), cow (by 68.4%), goat (by 73.3%) and camel (by 80.6%). Differences in goat MFG size (0.14–5.70 μm) with our results (0.34–6.99 μm) could be explained by different methods used during the study.

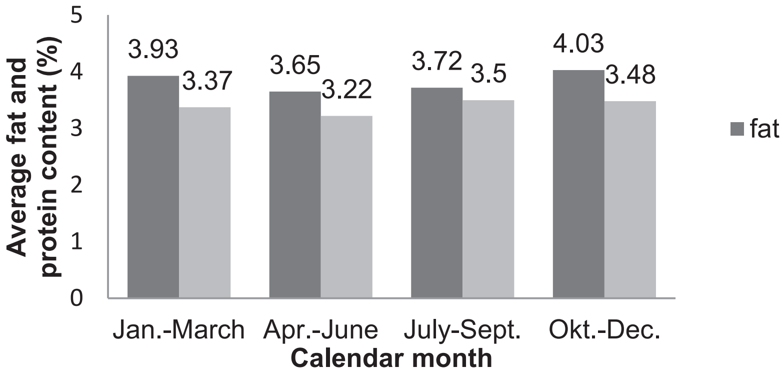

Figure 2. Average goat milk fat and protein content during different periods of the year.

Most fat globules (22.11%) in Estonian goat milk had a diameter of 1.5–1.99 µm, followed by 21.02% with diameter of 2.00–2.49 µm, and 16.05% of globules had diameter of 2.5–2.99 µm (Table 2). The smallest number of globules (0.03%) had diameter of 6.5–6.99 µm. Mean size of fat globules and their distribution did not considerably differ of these parameters in cow milk presented by El-Zeini (2006).

Table 2. Fat globules mean size distribution of goat milk compared to it in cow milk

Goat milk		**Cow milk***		**Goat milk****
MFG Diameter (µm)	Distribution, %	MFG Diameter (µm)	Distribution, %	Distribution, %
0.00–0.49	0.20			
0.50–0.99	5.74			
1.00–1.49	15.85	1–2	19.01	37.96
1.50–1.99	22.11			
2.00–2.49	21.02			
2.50–2.99	16.05	2–4	49.40	51.20
3.00–3.49	9.86			
3.50–3.99	4.27			
4.00–4.49	2.62			
4.50–4.99	0.89	4–6	19.61	4.14
5.00–5.49	0.38			
5.50–5.99	0.25			
6.00–6.49	0.08	6–8	3.59	0.11
6.50–6.99	0.03	≥8	8.36	

*El-Zenini (2006)
** Distribution % according to El-Zenini (2006) MFG diameter

Table 3 presents the descriptive statistics of MFG size characteristics. The average MFG diameter in different samples varied between 1.38 and 2.73 µm. The minimum and maximum MFG diameter was on an average 0.86 µm and 5.05 µm respectively. The total range of MFG size considering all milk samples exceeded from 0.34 µm to 6.99 µm.

Table 3. Descriptive statistics of MFG size characteristics

MFG size distribution characteristics	Average	Standard deviation	Minimum	Maximum
Average	2.22	0.388	1.38	2.73
Standard deviation	0.77	0.178	0.48	1.11
Minimum	0.86	0.283	0.34	1.38
Maximum	5.05	0.967	3.29	6.99

On an average over all milk samples the MFG size distribution was unimodal and lightly right skewed (Fig. 3). But distributions of individual samples were quite variable – there existed unimodal MFG size distributions with small variability as well multimodal MFG size distributions with large variability plus different kind of intermediate variants.

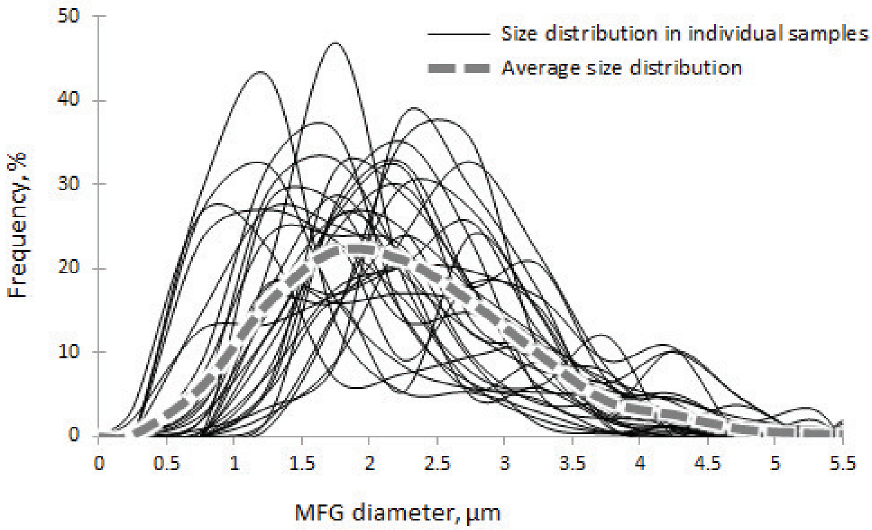

Figure 3. MFG size distribution in individual milk samples and average size distribution.

Our analyses revealed only some relationships between MFG size distribution characteristics and other traits. There was statistically significant intermediate positive correlation between average and standard deviation of MFG size distribution – the variability of MFG size was bigger if the average MFG size was bigger (correlation coefficient $r = 0.38$, $p = 0.037$; Fig. 4). Similar positive relationship was discovered between average MFG size and minimum and maximum MFG size.

There was only a weak negative and statistically non-significant correlation between average MFG diameter and milk fat percentage ($r = -0.10$, $p = 0.59$). The relationships of average MFG diameter with other milk parameters were even weaker. The correlations of minimal MFG diameter with milk fat and protein content were negative, intermediate and statistically significant ($r = -0.41$, $p = 0.023$ and $r = -0.46$, $p = 0.016$, respectively) – if the milk fat and protein percentage was higher, MFG-s were smaller.

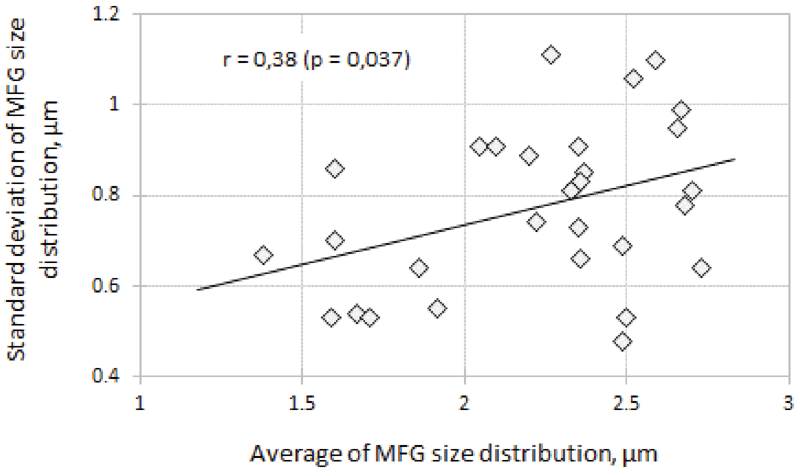

Figure 4. Relationship between average and standard deviation of MFG size distribution.

There was a negative intermediate statistically significant relationship between average MFG size and sampling month ($r = -0.46$, $p = 0.011$; Fig. 5). As this relationship may be caused also by the different sampling times in different farms and the number of samples in present study was quite small, the future research is needed.

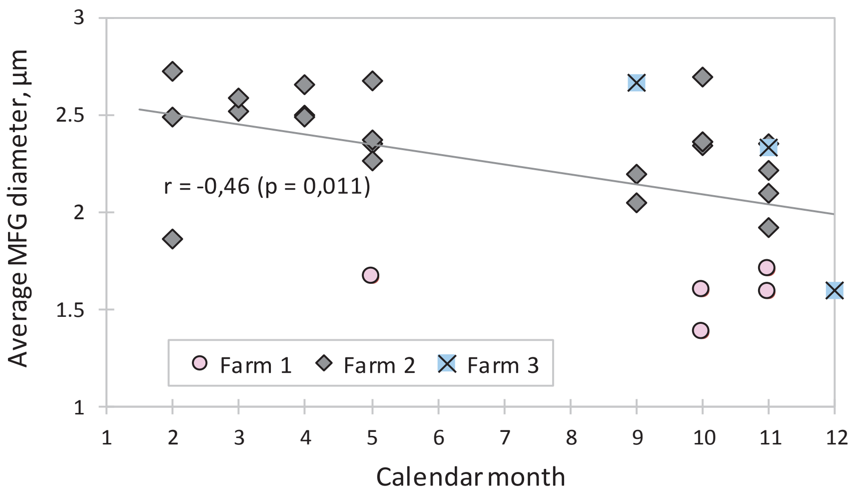

Figure 5. Average MFG diameter depending on the sampling month.

The average MFG diameter variation among farms was statistically significantly different ($p < 0.001$; analysis of variance), whereas this difference remained also after considering the effect of sampling month. The average MFG diameter in Farm 1 samples was on an average 0.78 and 0.61 µm smaller than the average MFG diameter in Farm 2 and Farm 3 samples ($p < 0.001$ and $p = 0.011$, respectively; Tukey *post-hoc* test; Fig. 6). Differences in MFG mean diameter may be influenced primarily by the structure of herds, especially concerning breed.

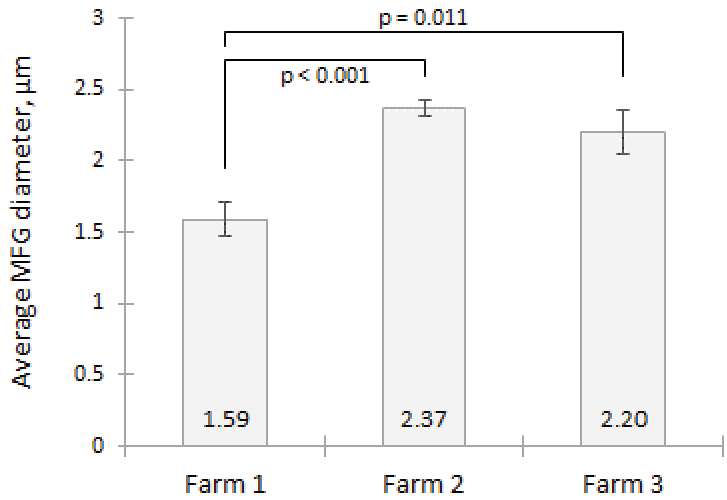

Figure 6. Average MFG diameter (± standard error) in different farms.

CONCLUSIONS

Differences in composition between Estonian goat and cow milk are quite small. The average total fat content in cow milk is higher and total protein content is less than that in goat milk a little bit. Range of fat and protein content (in comparison with cow's milk) is more extensive in goat milk. The average size of MFG and the size distribution range of particles in goat milk are quite similar to these parameters in cow`s milk although some differences do exist also. There was a small negative statistically not relevant link between fat content and the diameter of MFG in goat milk. However, some statistically relevant negative relations were revealed between the minimum size of milk fat globules and the content of fat and protein. The higher was fat and protein content in milk, the higher was the amount of minor fat globules.

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