Qualitative characteristics of sheep's and goat's milk in Albania

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Abstract

Cost-effective methods are crucial in small-scale operations to assess the physicochemical properties of milk, identify potential clinical or subclinical mastitis, and test β-lactams in small ruminants. The aim was to evaluate the importance of physicochemical characteristics, somatic cells, and antibacterial substances as factors for monitoring the quality and safety of bulk tank milk from sheep and goats. Furthermore, we aimed to elucidate the influence of grazing capacity on the composition of sheep milk. The fat content of sheep milk (n=119) was found to be 7.7%, with a range of 5.3% to 9.9%. The average fat content of dairy goats (n=33) was found to be 4.9%, with a range of 2.8-6.7%. The results indicate that 2.8% of sheep milk samples and 7.8% of goat milk samples exhibited clear positive reactions when assessed using the California mastitis test. β-lactam antibiotics were present in 0.7% of sheep milk samples, but not in any of the goat milk samples using lateral flow strips. This measurement method can be useful to detect adulterated milk and better understand the quality and safety of small ruminant milk before processing.

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Introduction

Milk from sheep and goats plays a significant cultural and nutritional role in many regions of the world. By 2030, sheep and goat milk productions are expected to rise by an additional 26% and 53%, respectively, following their dramatic increase over the past few decades (Pulina *et al*., 2018). The Food and Agriculture Organization (2015) reported that cattle accounted for approximately 85% of global milk production. Other species, such as buffalo, goat, sheep, and camel, contribute to the remaining milk production percentages of 11%, 2.3%, 1.4%, and 0.2%, respectively. Recent data shows that global milk production from goats has increased by approximately 31.5% and from sheep by around 17.5% since 2005 (Xhoxhi *et al*., 2024).

In Albania, small ruminants represent an important resource for the rural economy, which mainly uses them for meat and milk production. According to official data in Albania, the number of goats increased from 576,000 to 695,000 between 2010 and 2014. However, the number then started to decrease from 2014, reaching only 563,000 in 2022. Milk production was 84,000 tons in 2019, equaling 125 L per doe in 2019 (MoA and GIZ, 2021). Regarding the number of sheep, there was a slight increase from 1,337,000 in 2010 to 1,419,000 in 2014, followed by a decrease to only 1,085,000 in 2022. In terms of milk production, it was 82,000 tons in 2019, which is 65 L per ewe (MoA and GIZ, 2021). Yet, similar to the small ruminant population, milk production in Albania is decreasing following a period of steady growth. (Xhoxhi *et al*., 2024). According to the 2012 National Environment Agency pasture report, the productive level of the annual average wet mass of grass growth determines natural pastures' pasture management capacity. Based on wet mass, these managed natural pastures are divided into four productive groups (National Environment Agency, 2012).

The gross chemical composition of healthy goats and ewes has extensively been studied (Sheldrake *et al*., 1983; Leitner *et al*., 2004; Haenlein and Wendorff, 2006; Boulaaba, 2009; De Souza *et al*., 2009; Jendretzke, 2009; Li *et al*., 2022).

Table 1 shows the regional distribution and predominant breed of small ruminants in 2021 (UNDP, 2019; INSTAT, 2021).

In Albania, small ruminants face a variety of challenges related to the inadequate availability of milking equipment and refrigeration tanks on a significant proportion of dairy farms. The lack of adequate infrastructure presents a potential hazard to food safety, as the proper handling and storage of milk is essential for preserving its quality and mitigating the risk of contamination. Farmers may encounter difficulties adhering to the mandated standards and regulations for milk safety if they lack the essential equipment. Moreover, small-scale farmers of ruminant livestock often face the common challenge of insufficient awareness and knowledge pertaining to the Milk Quality National Minimum Standards. However, statutory parameters are laid down in the Albanian Standard (STASH). A significant proportion of agricultural practitioners may possess limited knowledge regarding the precise quality standards and stipulations of the production of milk. Insufficient comprehension of the subject matter can impede the individual's capacity to generate milk that aligns with the desired benchmarks of quality, thereby affecting its marketability and potential for profitability.

Bulk tank milk has the potential to be compromised by various contaminants, such as bacteria (including spoilage and pathogenic strains), bacterial and fungal toxins, veterinary drugs, cleaning and disinfectant agents, visible sediment, and other substances. These contaminants hold significant importance for farmers, cheese manufacturers, and consumers alike, as they play a crucial role, alongside somatic cells, in determining the safety and hygienic quality of the end product. Several parameters, including fat and protein contents, are subject to various legal limits or payment-by-quality schemes proposed by different countries. These regulations have significant implications for the marketing of sheep and goat milk (Pirisi *et al*., 2007).

The conductivity of milk has been used by researchers as an indicator of the severity of mastitis, which is an inflammatory process in the udder (Peaker and Linzell, 1975; Sheldrake *et al*., 1983). According to the initial findings of Smith and Sherman (1994), conductivity has been determined to be an ineffective measure for the detection of subclinical mastitis in goats. On the contrary, in ewe milk, this phenomenon was explored by Barth *et al*. (2008) who concluded that a higher sensitivity exists compared to cow milk. The results of the California mastitis test (CMT) can vary depending on the phase of lactation. In addition, the subjective judgment of the operator can influence the interpretation of the test results (Maisi *et al*., 1987). Enhancing breeding programs to optimize milk production, facilitating the widespread adoption of suitable milking equipment and cooling infrastructure, and providing comprehensive education and training to farmers to ensure milk quality standards and best practices are needed to address these challenges. Such measures may boost small ruminant dairy farming's growth and long-term viability, enabling the production of safe, high-quality milk. This paper discusses research on small ruminant milk physicochemical properties, somatic cell count, and antibacterial substances in Albanian counties.

Figure 1. Map visualization of ewe's milk processor. Locations of 14 processing plants collected in 142 farms.

Figure 2. Map visualization. Locations of 12 processing plants where the goat milk was collected from 51 farms.

Materials and Methods

Study area

In 2022, the locality from which bulk milk samples in small ruminants were collected included Sarandë (n=20), Fier (n=46), Dibër (n=19), Korçë (n=22), Përmet (n=12) Gjirokastër (n=46), and Durrës (n=8), located in Albania (Figures 1 and 2).

Overall, 193 farmers participated in milk sampling activities in nine Albanian counties. In addition, 142 samples, or 73.6% of the total, were associated with sheep milk, indicating that this matrix type was the most common during sampling. Also, 51 samples, or 26.4% of the total, were linked to goat milk (Figures 1 and 2).

Sample collection

Milk from sheep and goats was collected from the bulk tank early in the morning after milking, without considering the breeding of small ruminants. Before collecting the sample, the milk was promptly mixed to prevent fat globules from floating to the top as cream (Van Slyke, 1922). In most cases, milk was poured from one container into another with a sterile dipper (Goss, 1953). In other situations, the collected milk was stirred with an up-and-down, circular motion of a disk-shaped stirring rod (Goss, 1953; Davis, 1959). Subsequently, a 250-mL milk sample was obtained from each bulk tank and aseptically collected into sterile, dry, and clean bottles. Throughout the sampling and transportation process to the designated area of milk acceptance at processing plants, we maintained the samples at a temperature of 4°C. The samples were examined in duplicate for physicochemical screening tests for SCC and antibacterial residues (β-lactam).

Physicochemical testing

Sheep and goat milk were tested in each small dairy processing facility within 4 hours of collection. Milk compositions were measured with Lactoscan MCCW v1 (Milkotronic Ltd., Nova Zagora, Bulgaria) (Rai and Adhikari, 2022). This apparatus was calibrated with sheep, goat, and cow milk. Calibration of the instrument for fat determination was done against Gerber's method; density determination was done by using an aerometer, while solid non-fat (SNF), lactose content, salts, total protein content, freezing point, and added water content were done by formula according to manufacturer instructions. Overall, 11 parameters were tested in duplicates: temperature (°C), fat (%), SNF (%), density (kg/m^3), protein (%), lactose (%), salt (%), conductivity (mS/cm), pH, freezing point (°C), and added water. pH measurement was determined with a calibrated pH electrode.

Antibacterial screening test

The antibacterial screening test (PerkinElmer, Shelton, CT, USA) began by checking that the kit maintained a 20-30°C temperature range. After unsealing, reaction well covers were removed. After that, 200 uL of milk was added to each reaction well. The reaction was gently agitated with 10 vertical reciprocating movements for maximum uniformity. After that, the mixture was left alone for 3 minutes. After following the demarcation lines, the test strip was immersed in the reaction solution at the designated time. The lateral flow strip was soaked for 4 minutes. After the 4th minute, the test strip was extracted and cleansed to remove any milk residue in the lowest section. Instruction manual guidelines were followed to execute the interpretation scheme (Beltrán *et al*., 2013).

California mastitis test screening method

The initial step involved adding a volume of 2-3 mL of milk and distributing it into individual cups on a 4-cup plastic paddle. Following this, an equivalent quantity of the test reagent, comprising 3% alkyl lauryl sulfate and 1.5% sodium hydrate, with a pH indicator, is introduced into the milk (KEPRO, Kuipersweg 93449 JA, Woerden, The Netherlands). The paddle is subsequently rotated to homogenize the constituents. As a result of this mixing process, the mixture undergoes a discernible alteration in its hue, accompanied by the formation of a gel-like consistency within a time frame of 10±2 seconds following the instruction manual of the producer.

Statistical analysis

The resulting data were analyzed using SPSS for Windows (version 20.0.1, SPSS Inc., Chicago, IL, USA). One-way analysis of variance (ANOVA) with the Tukey honest significant difference test was used to investigate the significant difference in chemical parameters, somatic cell count, and β-lactam groups between different counties. A $p<0.05$ was considered statistically significant. To evaluate the statistical association between the physico-chemical components of sheep milk, grazing capacity, and geographical regions, a nonparametric correlation analysis using Spearman's rho was conducted. This approach facilitated the examination of both direct and indirect associations among variables.

Results

Physicochemical bulk tank milk

Statutory parameters laid down in Albanian legislation: fat in sheep milk 6% (STASH, 1987); SNF in sheep milk 11% (STASH, 1987); density in sheep milk (35-39) (STASH, 1987); fat in goat milk 4% (STASH, 1987); SNF in goat milk 8.5% (STASH, 1987); density in goat milk (29-34) (STASH, 1987).

Table 2 includes descriptive information and ANOVA statistics of normal physiological conditions in milk for a range of parameters. The results revealed notable differences in the analyzed parameters between sheep milk and goat milk. Goat milk showed less fat, SNF, density, protein, lactose, and salt than sheep milk, a similar approach to Table 1. However, conductivity and pH were found to be higher in goat milk. Freezing point depression was slightly lower in goat milk compared to sheep milk.

In ovine milk, the fat content ranges from 7.62% to 7.82%, with a minimum of 5.26% and a maximum of 9.94%. According to the established national standard outlined in STASH 1563-87 (STASH, 1987), the permissible fat content was set at 6%. The SNF content ranges from 11.01% to 11.11%, with a minimum of 8.45% and a maximum of 10.77%. The density ranged from 35.18 to 35.56 kg/m^3 (1000), with a minimum of 26.86 and a maximum of 38.69. According to STASH 1563-87, the accepted range for density at the national level is 35-39 kg/m^3 (STASH, 1987). The protein content ranged from 3.99% to 4.03%, with a minimum of 3.06% and a maximum of 4.53%. The lactose content ranged from 6.02% to 6.08%, with a minimum of 4.62% and a maximum of 6.86%. The salt content was consistently at 0.92%. The conductivity ranged from 4.39 to 4.49 mS/cm, with a minimum of 3.47 mS/cm and a maximum of 6.15 mS/cm. The pH resulted within the range of those of fresh ovine milk (Park *et al*., 2007) from 6.45 to 6.49, with a minimum of 5.27 and a maximum of 6.82. The freezing point ranged from -0.763 to -0.755°C, with a minimum of -

0.82 °C and a maximum of -0.553°C (Table 2). In dairy goats, the range for the amount of fat in the product was from 2.77% all the way up to 6.68%, with 4.71-5.05% in the range. The number given for the standard error was 0.17. According to STASH 1563-87, the level of fat content that must not exceed the legal limit was 4% (STASH, 1987). The SNF content ranged from 8.87% to 9.03%, with a minimum of 8.27% and a maximum of 10.63. According to STASH 1563-87, the national standard for SNF was set at 8.5%. The density of the samples is expressed as kg per m^3 (STASH, 1987). The density ranges from a low of 26.91 kg/m^3 to a high of 34.93 kg/m^3, with a mean value that fell between 29.48 and 30.02 kg/m^3. According to STASH 1563-87, the density range that constitutes the national standard range was 29-34 kg/m^3 (Table 2).

County comparison of fat and solid non-fat in ewe's milk

The maximum fat content is 8.50%, observed in the county of Përmet, while the minimum fat content is 6.38%, observed in the county of Durrës. The $p<0.05$ suggests that there are statistically significant differences in the fat content of ewe's milk between the counties, with Sarandë, Gjirokastër, Durrës, and Përmet. Overall, the fat content in ewe's milk varies among the counties, with Përmet having the highest fat content and Durrës having the lowest, and there are significant differences in fat content between some of the counties. The maximum SNF content was 11.18%, observed in the county of Përmet, while the minimum SNF content is 10.49%, observed in the county of Durrës (Table 2).

Comparison of California mastitis test score and by matrices and antibacterial substances.

A total of 130 samples from sheep milk were found to exhibit negative results, whereas 31 (60.78%) samples from goat milk were observed to display negative outcomes. A lesser percentage of samples exhibited weak positive outcomes, with 8 (5.63%) samples in sheep milk and 16 (31.37%) samples in goat milk. The quantity of positive samples was equivalent for both milk types, consisting of a total of four (2.82%) sheep and (7.84%) goat samples. β-lactam substances were detected in one farm out of 142 (0.7%) sheep milk, and no presence of β-lactam was found in 51 goat milk samples.

Analysis of correlation in sheep milk

Table 3 includes the results of a Spearman correlation analysis between grazing capacity, regions, fat percentage, and SNF composition, which have shown a strong correlation (-0.64) between regions and grazing capacity.

The fat content of sheep milk is positively correlated with grazing capacity (0.238) and SNF (0.397). SNF correlated poorly with regions (-0.13) and grazing capacities (0.198) (Table 3).

In Figures 3 and 4, the left y-axis shows grazing capacity in sheep/hectare/day, while the right axis shows our study's fat and SNF content. The x-axis shows established regions. Figure 3 illustrates that the coastal lowlands region has the lowest average maximum values of ewe's milk fat content compared to the central mountain region and the southern mountain region. On the other

Table 1. Regional distribution and predominant breed of small ruminants in 2021.

Counties	Sheep (000 heads) (a)	Predominant breeds (b)	Goats (000 heads) (a)	Predominant breeds (b)
Berat	121	Awassi,Cigajë	73.2	Autochthonus, Alpine
Dibër	70	Autochthonus,Rudë	40.3	Autochthonus, Mati
Durrës	27.6	Autochthonus,Rudë	21.1	Autochthonus, Mati
Fier	224.3	Recka	42.8	Aranitas
Gjirokastër	169	Autochthonus	93	Autochthonus
Korçë	244.4	Awassi,Cigajë	89.6	Autochthonus, Alpine
Lezhë	27.3	Bardhokë,Cigajë	51.1	Autochthonus, Alpine
Vlorë	351.5	Recka	162.3	Dukat, Dishat

(a), INSTAT, 2021; (b), UNDP, 2019.

Table 2. Principal constituents of goat and sheep milk considered in our study as normal physiological conditions.

	Sheep (n=119)			Goat (n=33)		
Parameters	Mean range	SE	Mi-Max	Mean range	SE	Mi-Max
Temperature (°C)	21.28-21.8(a)	0.26	15.71-28.21	23.78-25.08(a)	0.65	16.85-32.42
Fat (%)	7.62-7.82(a)	0.1	5.26-9.94	4.71-5.05(a)	0.17	2.77-6.68
SNF (%)	11.01-11.11(a)	0.05	8.45-12.64	8.87-9.03(a)	0.08	8.27-10.63
Density (kg/m^3)	35.18-35.56(a)	0.19	26.86-38.69	29.48-30.02(a)	0.27	26.91-34.93
Protein (%)	3.99-4.03(a)	0.02	3.06-4.53	3.23-3.29(a)	0.03	3.01-3.87
Lactose (%)	6.02-6.08(a)	0.03	4.62-6.86	4.86-4.94(a)	0.04	4.53-5.81
Salt (%)	0.92-0.92(a)	0	0.71-1.09	0.73-0.75(a)	0.01	0.68-0.88
Conductivity (mS/cm)	4.39-4.49(a)	0.05	3.47-6.15	6.36-6.68(a)	0.16	4.77-8.68
pH	6.45-6.49(a)	0.02	5.27-6.82	6.37-6.43(a)	0.03	5.71-6.95
Freezing point (°C)	(-0.763)-(-0.755)(a)	0.004	(-0.553)-(-0.820)(a)	(-0.590)-(-0.570)	0.01	(-0.530)-(-0.710)

SE, standard error; Mi-Max, minimum-maximum; SNF, solid non-fat; (a)significant differences between goat and sheep milk one-way analysis of variance (*t*-test) ($p<0.05$).

side, the central mountain region demonstrated the highest fat content in ewe's milk compared to other regions ($p<0.05$). It is evident from Figure 4 that the western lowlands exhibited lower values of SNF during the study period in comparison to the central mountainous region and the southern mountainous region.

The variation in SNF and fat percentage values can be attributed to variations in grazing capacities across different regions. In the present context, there is a demonstrated correlation between the province, fat percentage, and SNF when there are variations in grazing capacity values ($p<0.05$). This dataset holds significant evidence supporting the correlation between high grazing capacities and the corresponding values of fat and SNF, as indicated by the Spearman correlation rank coefficient of +0.238 for fat and +0.198 for SNF (Table 3).

Discussion

To the best of our knowledge, this is the first study to use field lab analysis to examine the composition and physicochemical properties of sheep and goat milk, as well as the impact of different regions on ewe's milk composition in Albania. County variations and sheep-goat differences are also discussed. A comparison of various physicochemical characteristics was conducted between sheep, providing comparative results between STASH regulatory parameters, set standards for small ruminant milk characteristics, and calibrated lactoscan equipment used in this study. Fat and SNF are in accordance with those reported in other studies (Cappio-Borlino *et al.*, 1997). Sheep milk exhibited higher SNF content, density, protein content, lactose content, and salt content compared to goat milk. Furthermore, goat milk exhibited a higher conductivity value compared to sheep milk, suggesting potential variations in electrical conductivity. Moreover, the freezing points of sheep milk were marginally lower than those of goat milk.

The analysis of the CMT scores in sheep milk and goat milk revealed a prevalence of possible mastitis in both milk types. Overall, we have a higher positivity percentage in goat milk compared to sheep milk. Grazing capacity in Albanian regions has the potential to positively or negatively influence the SNF and fat content of the ewe's milk ($p<0.05$). The use of pastures located at different altitudes (Gerchev and Mihaylova, 2012) and the diversity of natural feed intake in winter pastures could explain this effect.

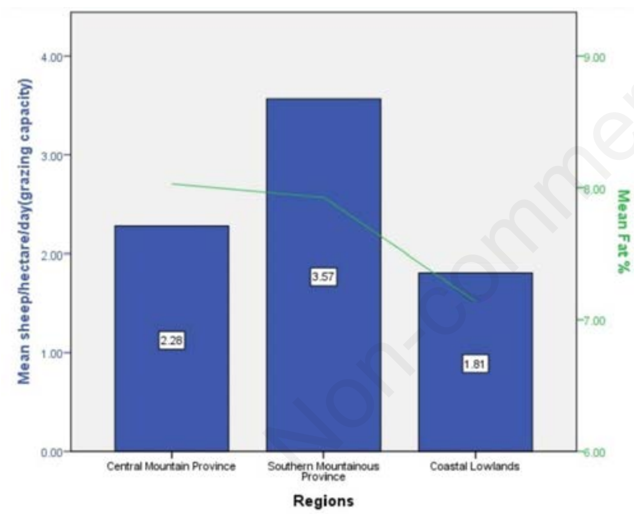

Figure 3. Mean fat percentage in sheep milk and variation of grazing capacity across geographic regions in Albania.

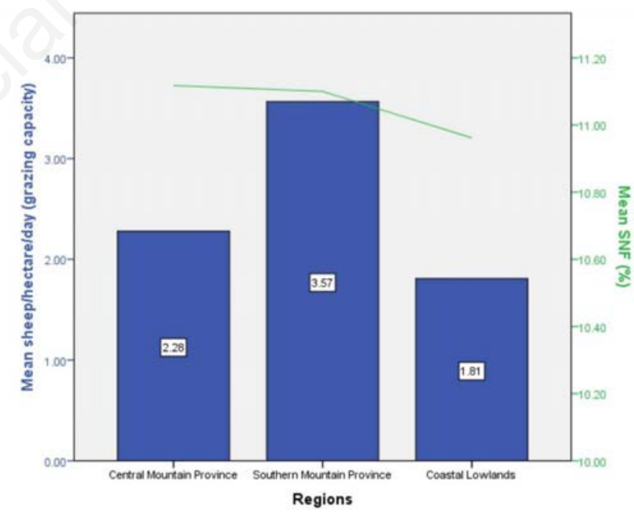

Figure 4. Mean solid non-fat percentage in sheep milk and variation of grazing capacity across geographic regions in Albania. SNF, solid non-fat.

Table 3. The relationship between two physicochemical properties regions, and grazing capacity in ewe's milk.

	Grazing capacity	Regions	Fat (%)	SNF (%)
Grazing capacity	1	-0.646**	0.238**	0.198*
Regions	-0.646**	1	-0.333**	-0.13
Fat (%)	0.238**	-0.333**	1	0.397**
SNF (%)	0.198*	-0.13	0.397**	1

SNF, solid non-fat; **p<0.01 level; *p<0.05 level.

Conclusions

The competitive advantage of products in the dairy sector depends on a comprehensive understanding of the composition and physicochemical properties of goat and sheep milk. These findings could help competent authorities in monitoring the milk quality of Albanian milk producers and processors. Additional investigation into intramammary infections and biological hazards in milk supply would be relevant.

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