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Influence of the farm location and seasonal fluctuations on the composition and properties of the milk

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Abstract. The aim of this research was to investigate the variations in the chemical composition as well as the physical and microbiological properties of raw milk depending on the farm location and the season. Seven dairy farms located in seven different geographic regions of Kosovo were included in the experiment. Milk composition (total solids – TS, milk fat – MF, solids non-fat – SNF, protein – P, lactose – L, active acidity – AA (pH), density – D, colony formatting unit – CFU, and somatic cells count – SCC) were analysed during a one-year period from December 2021 to November 2022. In a total of 252 analysed milk samples, the research showed an average good composition in accordance with the Kosovo regulation for milk quality: TS (13.71%), MF (5.12%), SNF (8.60%), P (3.25%), L (3.87%), AA (6.83), D (1.028 g cm^{-3}), but higher number of CFU (194,048 mL^{-1}), and SCC (418,429 mL^{-1}). Farm location showed significant differences ($P < 0.01$) in TS, MF, SNF, P, D, CFU and SCC, whereas L content and AA value were statistically non-significant. The lower value of TS, MF, and CFU were detected in summer, AA, and P in spring, SNF and L in autumn, D value was similar in all seasons, whereas only SCC was present in winter season. The differences in all analysed parameters with respect to the season were statistically non-significant.

Key words: milk composition and properties, farm location, season.

INTRODUCTION

Modern dairy farming in Kosovo is relatively new and still developing. Kosovo is a small and landlocked country in Southeastern Europe and strategically is positioned in the centre of the Balkan Peninsula. The territory of Kosovo is positioned between the Latitude: 42° 39' 50.18" N, Longitude: 21° 05' 46.00" E, and covers a surface area of 10,887 km^{-2} with an average altitude of 800 m above sea level. It is inhabited by 1.873 million inhabitants. Additionally, Kosovo is administratively subdivided into seven geographic regions (districts), such as (Prishtinë-Pr, Mitrovicë-M, Pejë-Pe, Prizren-Pz, Ferizaj-Fe, Gjilan-Gji, and Gjakovë-Gja) (Fig. 1). According to the Green report (2022), the cattle stock in Kosovo in 2021 was 260,528 heads. Dairy cows continue to have over 50% (132,076 heads) share in the total cattle stock. The total milk production in 2021 was 278,746 tons, which is about 2% higher than in 2020 because the number of dairy cows was higher. According to Bytyqi et al. (2009), daily milk yield differs from 12.34 to 18.92 kg per day depending on the cow breed. Milk consumption per capita was 171 kg per year, which means that a person consumes 0.47 kg per day including milk and its products.

Figure 1. The map of Kosovo.
Source: https://www.mapsofindia.com/world-map/kosovo/districts-and-capital-list-map.html

Milk represents a high-quality and valuable food for humans. According to Kabil et al. (2015), it can provide a wide range of readily available nutrients to maintain health and normal growth of organism. The composition and properties of milk are different and depend on many factors. These factors include species (Roy et al., 2020); breed (Kebede, 2018 and Sanjayaranj et al., 2022); stage of lactation (Mishra et al., 2022). However, the composition of milk is also largely affected by other factors i.e. season (Sahu et al., 2018; Gajbhiye et al., 2019; Li et al., 2019; Shibru et al., 2019; Czyzak-Runowska et al., 2020; Kheowsri et al., 2023; and Yap et al., 2024); as well as months of the year (Singh et al., 2018 and Araújo et al., 2023). Kabil et al. (2015) described seasonality of milk as the change in composition, quality, and suitability for processing into a dairy-based product throughout the year. According to Habteghiorghis (2019), seasonal changes in milk are result of regional climatic conditions. Additionally, milk composition can differ by the geographic location of the farms (Khatun et al., 2018; Asefa & Teshome, 2019 Mitani et al., 2021 and Yap et al., 2024) etc. Milk composition also differs among countries, because different countries use different breeds and feeding regimens, and have different calving patterns and breeding practices. In addition, altitude also plays important role (Alrhmoun, et al., 2023; and Ramadani et al., 2023). On the other hand, Timlin et al., 2021; Magan, 2021; and O'Callaghan et al., 2016 emphasize that milk production and composition can be directly influenced by the feeding systems. Among factors affecting milk composition and properties, a great importance has the frequency of milking - morning, evening milking (Singh et al., 2018), as well as weather conditions - rainfall and temperature ´- (Hayes et al., 2023). In addition, one of the most important factors to be mentioned is health of the animal (Kul et al., 2019; Özlem & Kul, 2020 and Ali et al., 2022), which cause economic losses in dairy farms (Azooz et al., 2020). The influence of these factors on the composition and properties of milk is well known and studied worldwide but is not sufficient under the conditions of Kosovo. Therefore, the aim of this research was to examine the influence of farm location and seasonal variations as factors affecting milk composition and characteristics under the conditions in Kosovo in the years 2021 and 2022, with a particular emphasis in the seven administrative regions mentioned above.

MATERIAL AND METHODS

Research design and milk sampling

According to the aim of this research, seven dairy farms located in seven above - mentioned regions of Kosovo were included. With the aim to preserve the confidence of the results, the farms are lettered A through G. Herd size in the farms were from 32–188 milking cows (Table 1). Dairy farms were composed with different dairy breeds, mostly predominantly by Holstein Friesian breed (specialized dairy) and Simmental breed (dual-purpose: milk and meat production). The dairy cows in this research were kept indoors throughout the research period, in tie-up keeping, and in some cases with loose keeping. The animals did not use grazing in warm weather but were mainly fed with pre-prepared dry feed. In all season's animals were fed hay and haylage, with the addition of concentrated feed. Cows were milked twice a day at 06:00 h and 18:00 h daily, and raw milk was collected in farm cooling tanks.

Table 1. The research design of milk sampling

Region/farm	Number of cows (multi-breed herds)	Simmental breed (dual-purpose)	HF breed (specialized dairy)	Sample per Region/farm for one year	Sample replication	Total samples per Region/farm
Pr/A	36	17	19	12	3	36
M/B	188	152	36	12	3	36
Pe/C	29	13	16	12	3	36
Pz/D	107	-	107	12	3	36
Fe/E	32	20	12	12	3	36
Gji/F	46	27	19	12	3	36
Gja/G	62	7	62	12	3	36
	500	236	271			
Total samples per research						252

Sample preparations of fresh raw milk for analysis.

After the complete milking, raw bulk milk in the farm cooling tanks was thoroughly mixed. The milk sampling was carried out once per month during the period from December 2021 to November 2022. Seasonal variations included spring (March, April, and May), summer (June, July, and August) autumn (September, October, and November) and winter (December, January, and February). A total of 252 milk samples with about 250 mL were collected in a plastic flask according to ISO 707:2008 (IDF 50:2008), (2008). Samples were conserved with 0.03% sodium azide, and with a portable hand-held mini refrigerator transported immediately at a temperature of 4–8 °C to the laboratory of the Food Technology with Biotechnology in the Faculty of Agriculture and Veterinary - University of Prishtina, for physical-chemical and microbiological analyses. For analysis, milk samples in a bottle were heated to around 40 °C in a water bath. The samples were then stirred and poured to allow the melted milk fat to emulsify. The sample was then cooled to approx. 20 °C.

Milk analyses

The analyses of raw milk samples were carried out on the following methods and instruments: MF, SNF, P, L and D were analysed with the 'Lactostar' - Funke Gerber 3510-070702, Germany, based on a combined thermo-optical procedure. TS content was calculated using MF and SNF values. AA value was measured by using pH meter GLP 21 'Crison' (ISO 11869:2012). CFU is analysed by the method of counting colonies of microorganisms in nutrient bases (agar-agar) and following the standard procedures recommended by ISO 4833–2:2013, whereas SCC was measured with the somatic cell counter MT05. The principle of method is based on adding to the milk a substance which causes a change in viscosity of the milk proportional to the quantity of somatic cells. Through measuring the viscosity of the milk sample, it is possible to measure the number of somatic cells. All analyses of raw milk were carried out in triplicate.

Statistical analyses

The obtained results were statistically analysed using the JMP-IN 7.0 statistical package (SASS unit) to find the influence of the farm location and the season in the chemical composition as well as the physical and microbiological properties of raw milk. The results of the analyses are presented in tabular form and were expressed as mean ± standard error of mean (SEM). To find whether significant differences exist, one way Anova was used, and if significance was observed, the Tukey's post hock test was used to find where and to what extent these differences are. The borderline of significance was set at the alfa level of 0.01.

RESULTS AND DISCUSSION

The influence of the farm location on the composition and properties of milk

The results regarding the influence of the farm location on the composition and properties of milk are presented in the Table 2 and 3.

Table 2. Milk composition depending on region/farm location (Mean ± SEM) (n = 252)

Region/farm location	TS (%)	MF (%)	SNF (%)	P (%)	L (%)
Pr/A	14.82 ± 0.51^{ab}	6.23 ± 0.56^{ab}	8.59 ± 0.15^{bcd}	3.57 ± 0.16^{ab}	3.50 ± 0.15
M/B	13.26 ± 0.52^{c}	4.58 ± 0.55^{bc}	8.68 ± 0.15^{bc}	3.01 ± 0.08^{c}	4.16 ± 0.12
Pe/C	13.60 ± 0.13^{bc}	4.35 ± 0.09^{c}	9.25 ± 0.05^{a}	3.69 ± 0.05^{a}	4.00 ± 0.08
Pz/D	13.32 ± 0.34^{c}	5.13 ± 0.42^{bc}	8.20 ± 0.16^{cd}	2.99 ± 0.10^{c}	3.72 ± 0.10
Fe/E	15.11 ± 0.23^{a}	7.31 ± 0.72^{a}	8.10 ± 0.21^{d}	3.13 ± 0.16^{c}	3.75 ± 0.12
Gji/F	13.20 ± 0.44^{c}	4.27 ± 0.33^{c}	8.74 ± 0.09^{ab}	3.21 ± 0.07^{bc}	3.99 ± 0.07
Gja/G	12.66 ± 0.14^{c}	3.99 ± 0.07^{c}	8.67 ± 0.07^{bc}	3.12 ± 0.06^{c}	4.00 ± 0.07
P	<.0001	<.0001	<.0001	<.0001	ns

TS – Total solids (%), MF – Milk fat (%); SNF – Solids non-fat (%); P – Proteins (%); L– Lactose (%); ns – non-significant. ^{a,b,c}Means with different superscript in the same column differ significantly ($P < 0.01$).

Based on the results presented in the Table 2, it is observed that content of the total solids has shown values within the limits prescribed in Administrative instruction MA 20/2006. The average value of this parameter was 13.71% (from 12.66 ± 0.14% to 15.11 ± 0.23%). This value is relatively high and good for milk processing, especially for cheese production. Among the analysed farms, TS showed variations that were statistically significant ($P < 0.01$). Possible reason of differences observed between regions could be due to differences in farming practices or breed structure of the farms. Mean value of TS in this research is almost similar with results reported by Khatun et al. (2018), which observed significant differences in TS (13.62%; 13.15% and 14.12%) between farms in three different regions (South-Central, North-Western, and Western regions) of Bangladesh. A slightly lower value of TS reached Kouřimská et al. (2014) in their investigation with the aim to compare organic and conventional farming systems. They found higher contents of TS (12.73%) in conventional farming, compare to 12.69% in organic farming, emphasizing that differences could have been affected by the feeding composition which differs between organic and conventional farming systems. A slightly lower content of TS (12.72–13.3%) was reported by Yap et al. (2024) during evaluation of the quality of raw milk produced from nine different locations across Ireland over 12 months.

Milk fat content has shown values of 3.99 ± 0.07% (farm G) to 7.31 ± 0.72% (farm E). Differences in MF between farms could be described to feeding composition and regimes. The mean value of MF (5.12%) can be considered as a high valuable content. A valuable milk product with a high MF content (milk cream, buttermilk), etc. can be obtained from this milk. Among the farms analysed in this research, MF showed variations that were significantly different ($P < 0.01$). The results of this research are higher compared with the results reported by Kunda et al. (2015). They found out significantly different ($P > 0.05$) MF content averaging 3.90% (3.85% and 5.10%) in 83 farms around the two largest cities in Burkina Faso. Lower content of MF compared to ours reported Kouřimská et al. (2014) in analysed raw milk samples coming from organic and conventional farming systems. They stated higher contents of MF (4.03%) in organic farming, compared to 3.99% in conventional farming. Gaworski et al. (2018) in eight Estonian dairy farms with automatic milking system, milking parlour, and pipeline milking system, obtained these results for milk fat content (Mean ± SD): respectively 3.99 ± 0.08%, 3.91 ± 0.21% and 4.26 ± 0.33%. In addition, lower content of MF compared to ours was reported by Kvapilík et al. (2017), who obtained the MF 3.84% (from 3.23% to 4.46%) of the 522 monthly bulk milk samples from 11 experimental farms. Also, Nyokabi et al. (2021) reported lower content of milk fat (3.61%) compared to our results and stated no differences in the quality of raw milk between locations.

The solids non-fat content resulted in an average value of 8.60% (from 8.10 ± 0.21% to 8.74 ± 0.09%) and is therefore within the limits provided for in Administrative Instruction MA 20/2006. Among the farms analysed, SNF showed variations that were statistically significant at the $P < 0.01$ level. In two farms (D, E), the milk analysed showed lower values than those provided in the above-mentioned regulation, according to which milk with an SNF content of less than 8.50% is considered adulterated by the addition of water. However, this doubt does not exist because the authors of the research strictly carried out the activities from milking to sampling, therefore low values can be attributed to other possible factors. Results obtained in this research seems to be lower, compared to those reported by Nyokabi et al. (2021) in the amount of 9.18%, which stated no differences in the quality of raw milk between locations. The higher content of SNF (9.30%) in milk of 83 farms is also reported by Kunda et al. (2015).

The overall mean of protein content (3.25%) in this research was within Kosovo standards for milk quality. The lowest value of this parameter was on the farm D (2.99 ± 0.10%) and farm B (3.01 ± 0.08%), which could be ascribed to feeding management. The highest value of protein content was detected on the farm C (3.69 ± 0.05%). Generally, milk with such protein content, could be a good resource for milk products, especially for cheese production. Among the farms analysed, P content showed variations that were statistically significant at the $P < 0.01$ level. Nyokabi et al. (2021) reported a slightly higher content of milk P (3.46%) compared to our results. Petrovska et al. (2017) in individual milk samples from the Latvian cow breeds, collected across different Latvian regions, obtained results for P content in amount of 3.45%, 3.50% and 3.43% respectively. Kvapilík et al. (2017) found that P content of bulk milk samples from 11 experimental farms was 3.39% (from 3.04 to 3.75%). In addition, Kunda et al. (2015), found out P content in milk of 83 farms in amount of 3.70%.

The lactose content in this research was not at the desired level. The lower content is registered on the farm A (3.50 ± 0.15%) whereas the higher on the farm B (4.16 ± 0.12%). The mean value of this parameter was 3.87%, which is significantly lower than the normal value provided by the regulation. The low lactose content of milk is an important indicator of milk quality, which could be due to the high SCC as well as low energy intake and malnutrition. Therefore, better hygiene and feeding management should be carried out on the farms to improve lactose content as well as milk quality in general. The lactose content in this research is lower to those reported by Rahman et al. (2014) in cows of two different regions of Bangladesh (both 5.29%), with non-significant differences. Ruska et al. (2017) analysed cow milk in farms located in different Latvia region with different holding system and obtained L content in amount of 4.65% and 4.71% with significant differences ($P < 0.05$). Kouřimská et al. (2014) in their research reached results for L content (4.84%) in conventional farming, compared to 4.80% in organic farming with significant differences. Yap et al. (2024) in 9 farms observed L content of 4.58 – 4.81% during evaluation of the quality of raw milk produced from nine different locations across Ireland over 12 months.

Table 3. Some physical properties, bacteriological quality and SCC of milk depending on region/farm location (mean ± SEM) ($n = 252$)

Region/farm location	AA (pH)	D (g cm^{-3})	CFU mL^{-1}	SCC mL^{-1}
Pr/A	6.83 ± 0.08	1.026 ± 0.00^{bc}	138,750 ± 37,387^{bc}	541,667 ± 63,614^{a}
M/B	6.76 ± 0.11	1.029 ± 0.00^{ab}	116,667 ± 24,721^{c}	300,000 ± 42,580^{c}
Pe/C	6.74 ± 0.07	1.031 ± 0.00^{a}	259,167 ± 45,167^{b}	483,333 ± 41,439^{ab}
Pz/D	6.98 ± 0.07	1.027 ± 0.00^{bc}	138,333 ± 26,136^{bc}	575,000 ± 58,225^{a}
Fe/E	6.88 ± 0.06	1.024 ± 0.00^{c}	136,250 ± 29,549^{bc}	575,000 ± 53,831^{a}
Gji/F	6.81 ± 0.12	1.029 ± 0.00^{ab}	115,000 ± 19,365^{c}	370,833 ± 34,520^{bc}
Gja/G	6.81 ± 0.09	1.030 ± 0.00^{a}	454,167 ± 50,923^{a}	83,167 ± 1,854^{d}
P	ns	<.0001	<.0001	<.0001

AA – Active acidity (pH); D – Density (g cm^{-3}); CFU – Colony Formatting Unit (CFU mL^{-1}); SCC – Somatic Cell Count (SCC mL^{-1}); ns – non-significant. ^{a,b,c}Means with different superscript in the same column differ significantly ($P < 0.01$).

The mean value of active acidity (pH = 6.83) was a slightly higher than frames of the Kosovo standards for milk quality for this parameter. A higher pH value indicates a mastitis infection in the cow. As in the case of lactose, the hygiene management of the farm and dairy cows should be necessary and continuous, with the aim of ensuring healthy and high-quality milk. Among the farms analysed, AA showed statistically non-significant differences at the $P < 0.01$ level. A lower value compared to ours reported Asefa & Teshome (2019). They stated a significant difference between each study site with the lower pH of 6.02 and 6.17 in Debrezeit and Sebeta milk shade whereas in milk from Wolmera and Selale cloth to normal pH range.

Milk density on all farms was within the limits for normal and unadulterated milk. The overall mean value was 1.028 g cm^{-3} (1.024 to 1.031 g cm^{-3}), with variations that were statistically significant at the $P < 0.01$ level. The differences between lower and higher density values could be due to changes in total solids content. Asefa & Teshome (2019) reported almost similar results of density (1.029, 1.030, 1.029 and 1.031 g cm^{-3}) of milk samples from different locations, but with no significant ($P > 0.05$) difference. In addition, Nyokabi et al. (2021) reported a slightly higher value of milk density (1.031 g cm^{-3}) compared to our results and stated significant differences between locations.

The average value of CFU (194,048 mL^{-1}) was significantly above the threshold provided by the Kosovo regulation (< 80,000 mL^{-1}), and the analysed milk was categorized in the second quality class (< 300,000 CFU mL^{-1}). This may be attributed to poor hygiene practices that may have been implemented in these farms. It is recommended that in the future more work should be done to diligently implement hygienic measures on farms, with the aim of improving the microbiological quality of milk. However, this would affect the maintenance of the animals' health condition, but also the improvement of the milk payment, which is based, among other things, on the values of this parameter. In comparation to our results for this parameter, Kvapilík et al. (2017) found higher contents (250,000 mL^{-1}) in the bulk milk samples from 11 experimental farms during the period from 2012 to 2015. Contrary to this, Kouřimská et al. (2014) in conventional and in organic farming concluded contents of CFU (48,000 mL^{-1} and 45,000 mL^{-1} respectively), which are much lower compared to ours. Ivanov et al. (2017) found in milk samples from three regions of western Turkey that the maximum permissible values of 100,000 CFU mL^{-1} were exceeded and there were no statistically significant ($P < 0.05$) differences.

The average number of SCC (418,429 SCC mL^{-1}) although a little high, was almost within the limits for normal milk derived from healthy animals, and according to the Kosovo regulation it is categorized in the second quality class. Only farm B, F and G showed good results of SCC. However, the results recommend implementing the best hygienic practices to improve the quality of milk and healthy status of milking animals. These measures are necessary to prevent the occurrence of breast diseases that could, among other things, cause economic damage. Among the farms analysed, SCC showed variations that were statistically significant at the $P < 0.01$ level. Kouřimská et al. (2014) reported lower contents of SCC in conventional (230,000 mL^{-1}) and organic farming (218,000 mL^{-1}) compared to ours. Lower contents of SCC also reported Leso et al. (2019). He studied 30 commercial dairy farms located in the Po Valley, Italy over a period of one year. SCC was between 259,000 mL^{-1} and 354,000 mL^{-1}. Ducková et al. (2019) reported higher mean value of SCC (50,767 mL^{-1}) in milk samples from farm dairies compared to ours. Ivanov et al. (2017) found very high SCC levels in milk samples from three regions of western Turkey. These values are well above the maximum permitted by European legislation of 400,000 mL^{-1} in cow's milk.

The influence of the seasonal fluctuations on the composition and properties of milk

Based on the results presented in Table 4 and 5, it can be noted that all analysed indicators showed slight fluctuations within seasons with statistically non-significant differences.

Total solids content showed an average value of 13.71%, which meets the quality standards for milk in Kosovo. The lowest value was in the summer season (13.55 ± 0.32%) while the highest was in the spring season (13.97 ± 0.38%). The differences between the seasons were statistically non-significant. This can be justified by the fact that on all farms the animals were kept in an indoor system and were mainly fed with the almost similar pre-prepared dry feed, while the feed from free pasture has not been applied. Baset et al. (2016) reported that season (dry and wet) did not affect TS. This finding is consistent with the results obtained in our research. However, many other authors emphasize the influence of the season on changes in the value of TS in milk. Thus, Kabil et al. (2015) reported seasonal influence in mean values of TS, which in winter was 12.40%, and in summer 11.10% respectively. Both winter and summer values of TS were lower, compared to results in our research. Lower TS values in the summer season were also reported by Cowley et al. (2015). He dealt with the fact that days in summer are getting longer, and the temperature is rising, which results in heat stress to cows, decreases dry matter intake (DMI) in cattle, and that also declines milk production. Sahu et al. (2018) found that the overall mean for TS content of milk was 12.61%. He also showed non-significant influence of seasons on TS content of milk of Kosali cows, being highest in rainy season (12.81%) followed by winter (12.67%) and lowest in summer season (12.36%). According to Shibru et al. (2019), TS content was higher in dry season from October to May (13.38%) and lower in wet season from June to September (12.96%) with non-significant differences. Parmar et al. (2020) showed significantly higher value of TS in autumn (14.72%), compared to spring (13.95%) and summer (13.68%). Nateghi et al. (2014) suggested that summer milk has significantly higher TS content (13.31%) than winter milk (12.02%).

Table 4. Milk quality depending on season (Mean ± SEM) (*n* = 252)

Season	TS (%)	MF (%)	SNF (%)	P (%)	L (%)
Spring	13.97 ± 0.38	5.29 ± 0.43	8.57 ± 0.14	3.16 ± 0.10	4.02 ± 0.05
Summer	13.55 ± 0.32	4.88 ± 0.33	8.63 ± 0.13	3.24 ± 0.13	3.94 ± 0.11
Autumn	13.58 ± 0.31	4.97 ± 0.36	8.55 ± 0.11	3.27 ± 0.07	3.74 ± 0.10
Winter	13.73 ± 0.29	5.35 ± 0.52	8.67 ± 0.13	3.32 ± 0.08	3.80 ± 0.08
P	ns	ns	ns	ns	ns

TS – Total solids (%); MF – Milk fat (%); SNF – Solids non-fat (%); P – Proteins (%); L – Lactose (%); ns – non-significant.

Milk fat is considered one of the quality parameters that varies depending on various factors, including the influence of the season. MF content in the samples collected in the summer (4.88 ± 0.33%) was non-significantly lower compared with samples of winter season (5.35 ± 0.52%), with the average value of 5.12%. The slightly lower MF during summer season could be attributed to differences in nutrient intake or specific effects of climate such as environmental temperature. Statement regarding non-significantly differences of MF in our research is consistent with the statements of

Madruga et al. (2016), who reported that the MF content did not vary according to the seasons. On the other hand, Kabil (2015) reported a significant seasonal influence in cows MF with lower mean values in summer (3.10%) compared to winter (3.60%). Pacheco-Pappenheim et al. (2021) reported that MF levels were significantly higher ($P < 0.05$) between months, where the maximum content was observed in March (4.60%) and the minimum in June (4.08%). Also, according to Gajbhiye et al. (2019) MF content was significantly different between seasons ($P < 0.01$). The highest MF content being produced in the Rainy-winter season (4.34% and 4.26%) and lowest in Spring-Summer season (4.14% and 3.88%). Habteghiorghis (2019) in his research showed significant variation of MF ($P < 0.05$) between different seasons. The highest average of MF content (6.15%) was recorded in autumn, while the lowest (4.73%) was in spring. Czyzak-Runowska et al. (2020) reported significantly higher MF content ($P \leq 0.01$) in autumn-winter (3.79%) while lower content in spring-summer season (3.19%). Parmar et al. (2020) reported significantly higher content of MF in autumn (5.13%) and spring (5.00%) than in summer (4.71%). Bertocchi et al. (2014) reported significantly higher amount of MF in winter (4.01%) and autumn (3.91%) than in spring (3.85%) and summer (3.75%). Looper (2014) also reported the highest MF content during the autumn and winter, and lowest during the spring and summer season, reasoning mainly due to changes in both the types of feed availability and climatic conditions.

Solids non-fat content showed an average value of 8.60%. The lowest value was in the autumn season ($8.55 \pm 0.11\%$) while the highest was in the winter season ($8.67 \pm 0.13\%$), with statistically non-significant differences between seasons. However, a slightly lower SNF value in autumn could be due to feed composition or other factors (e.g. environmental conditions, temperature, etc.). SNF content in all seasons was under limits, prescribed in Administrative instructions of Kosovo for good and unadulterated milk. These findings are almost consistent with those emphasized by Singh et al. (2018), who reported average value of SNF 8.72% with the range from 7.97% in summer to 9.42% in winter season. Wangdi et al. (2016) recorded overall mean milk composition in milk produced in Bhutan and find out that SNF content was lower in spring and summer (8.35%), than in winter (8.40%) and autumn (8.61%). Mishra et al. (2022) found that SNF content varied by season and was highest in winter (9.46%), followed by summer (9.31%) and rainy season (8.92%). Kheowsri et al. (2023) reported that the SNF was significantly ($P < 0.01$) lower in the rainy (8.51%), in comparison to cold (8.54%) and hot season (8.55%).

Protein content of milk is highly important due to influence on its nutritional value and processing properties, since milk protein content may increase milk product yield such as cheese. The mean value of milk protein in this research was 3.25%. The lowest protein content in this research was detected in the spring season ($3.16 \pm 0.10\%$). It could be as a results of feed availability and climatic conditions. The highest content was registered in the winter season ($3.32\% \pm 0.08$) However, non-significant differences were detected between seasons. Similar conclusions emphasised in their research Baset et al. (2016); Wangdi et al. (2016); Lin et al. (2017). Contrary to this, Kabil, (2015) reported higher values of P in winter (3.50%) compared to summer (3.10%) respectively. Sahu et al. (2018) reported significantly differences of P levels between the seasons ($P < 0.01$), in which case the higher levels were registered in winter season (3.13%) followed by summer (2.98%) and lowest in the rainy season (2.82%). However, the noted that the mean differences between summer and rainy season were nonsignificant. Chanda et al. (2021) reported average value of P (3.45%) in winter and 3.36% in summer with significantly differences ($P < 0.05$). In addition, Bertocchi et al. (2014) reported higher content of P during winter (3.44%) and autumn (3.48%) compared to spring (3.39%) and in summer (3.32%). Similar to this, Looper (2014) reported that the highest *P* content was recorded during the autumn and winter, and lowest during the spring and summer season resulting mainly due to changes in both the types of feed availability and climatic conditions.

The average lactose content in this study was 3.87%, which can be considered low for normal milk. In addition, lower values were found in all seasons. This could be related to several genetic factors and the health of the mammary gland. For this reason, maintaining general hygiene and udder health should be a necessary activity on all farms. Differences between the autumn season (3.74 ± 0.10%) and spring season (4.02 ± 0.05%) were statistically non-significant. Almost all authors cited below reported a higher amount of L in their research. Some of them (Parmar et al., 2020) obtained higher L amount in the autumn (4.68%) compared to spring (4.59%) and summer (4.62%). Sahu et al. (2018) reported that L level was significantly higher ($P < 0.01$) during the winter (4.69%) and lower in the summer (4.49%) and rainy season (4.22%). On the other hand, Baset et al. (2016) reported that season (dry and wet) did not affect L content. Nateghi et al. (2014) noted non-significant difference regarding L content between summer (4.61%) and winter milks (4.58%) respectively.

Table 5. Some physical properties, bacteriological quality and SCC of milk depending on season (Mean ± SEM) ($n = 252$)

Season	AA (pH)	D (g cm^{-3})	CFU mL^{-1}	SCC mL^{-1}
Spring	7.05 ± 0.26	1.028 ± 0.00	222,857 ± 43,612	447,857 ± 50,996
Summer	7.17 ± 0.29	1.028 ± 0.00	174,762 ± 23,408	445,000 ± 50,509
Autumn	7.54 ± 0.22	1.028 ± 0.00	189,524 ± 36,097	433,714 ± 51,168
Winter	7.47 ± 0.25	1.029 ± 0.00	189,048 ± 39,430	347,143 ± 41,000
P	ns	ns	ns	ns

AA – Active acidity (pH); D – Density (g cm^{-3}); CFU – Colony Formatting Unit (CFU mL^{-1}); SCC – Somatic Cell Count (SCC mL^{-1}); ns – non-significant.

The active acidity (pH) value of fresh whole cow milk normally varies within a quite narrow range of 6.5 and 6.8. In this study, this parameter could be considered slightly high because there is a high probability that it indicates udder inflammation. The lowest value of AA was in the spring (7.05 ± 0.26) while the highest was in the autumn (7.54 ± 0.22), with an average value of 7.31 and non-significant differences between seasons. This is consistent with the results obtained from Lin et al. (2017), who emphasized that season did not significantly affect AA value. Contrary to this, the statistically significant differences of pH between the seasons reported Özlem & Kul. (2020) with highest value in winter (6.76) and lowest value in spring (6.33). In addition, Habteghiorghis (2019) noted a significant variation ($P < 0.05$) in AA value between the samples from different seasons. Thus, the highest AA value recorded in winter (6.72) and lowest in summer (6.67).

The milk density in this research showed the mean value of 1.028 g cm^{-3}, which meets the requirements of the regulation for normal and undiluted milk. The lowest value was in the spring, summer, and autumn (1.028 g cm^{-3}) while the highest was in the winter season (1.029 g cm^{-3}). The differences between the seasons were statistically non-significant. Similar results to ours reported Wangdi et al. (2016) with the D value of 1.028 g cm^{-3} in all seasons and non-significant differences. Moreover, Nateghi et al. (2014) noted that D value of summer and winter milks were 1.032 g cm^{-3} and 1.030 g cm^{-3} respectively, being statistically similar (non-significant). Contrary to this, Parmar et al. (2020) obtained the highest D value in the summer (1.0314 g cm^{-3}) while the lowest in the spring (1.0304 g cm^{-3}) with significant differences in all the seasons.

Analysed milk in our research showed the mean value of 194,048 CFU mL^{-1}. This value significantly exceeds the limit for extra class described in the regulation (80,000 CFU mL^{-1}). This can be attributed to lack of hygienic conditions during milking and handling of the milk. The lowest value was in the summer season (174,762 ± 23,408) while the highest was in the spring season (222,857 ± 43,612). The differences between the seasons were statistically non-significant. Hajmohammadi et al. (2021) noted that the samples collected in summer had higher ($P < 0.05$) CFU mL^{-1} than in winter, highlighting that these results indicate that most of the traditional milk production in the studied region occurs under unsatisfactory hygienic conditions. Like this, Bertocchi et al. (2014) found an increase in CFU during the summer months and emphasized that this is closely related to the greater bacterial growth and higher contamination of the udder compared to the other seasons. Contrary to this, Nateghi et al. (2014) gained a significantly higher microbial load of winter milk (78,262.54 CFU mL^{-1}) than that of summer milk (72,345.12 CFU mL^{-1}) suggesting that summer milk was produced under more favourable hygienic conditions.

The somatic cell counts in this research gave a mean value of 418,429 SCC mL^{-1}. The lowest value was in the winter season (347,143 ± 41,000) while the highest in the spring season (447,857 ± 50,996) and summer season (445,000 ± 50,509). These levels are relatively high, especially in the spring and summer season, which can lead to health problems of the mammary gland. Between seasons statistically non-significant differences were detected for this parameter. Contrary to this, Kheowsri et al. (2023) reported a significantly highest SCC in the rainy season (321.21 ± 3.93 x 1,000 cell mL^{-1}), and the lowest in cold season (297.29 ± 94.34 x 1,000 cell mL^{-1}). In addition, Heck et al. (2009) determined a minimum of SCC value in the winter and a maximum value in the summer season. Similar findings were offered by Bertocchi et al. (2014) and Hajmohammadi et al. (2021) reporting that the SCC was higher in the summer months.

CONCLUSIONS

Based on the results obtained in this research, it can be concluded that the geographical location of farms in Kosovo during 2021 and 2022, with the focus on the seven administrative regions significantly influenced majority of tested milk parameters, such as: TS, MF, SNF, P, D, CFU, and SCC. However, this factor did not significantly influence L content and AA value.

On the other hand, season did not have a significant influence on the measured parameters. Nevertheless, lower levels of TS, MF, and CFU in summer; AA and P in spring; SNF and L in autumn, and SCC in the winter season were observed.

Based on these findings, it is recommended for farmers to continue working in better hygienic practices on their farms to further improve milk quality and the health of milking animals. Additionally, further research, especially regarding the influence of feeding and overall farm management practices, is suggested to better identify factors that influenced the variations in milk quality between farms and seasons observed in this research.

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