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ORIGINAL PAPER

Analysis of the composition and physicochemical properties of milk from Simmental and Holstein cows in the Dukagjin Plain region, Kosovo

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Abstract

This comprehensive study delves into the influence of breed on milk's physicochemical and mineral properties from Simmental and Holstein cows in Kosovo's agriculturally significant Dukagjin Plain region. Milk samples were meticulously gathered from five distinct municipalities within this region, and their composition was rigorously analyzed using standardized laboratory methods to ensure accuracy and reliability. The findings underscore a notable breed effect on milk fat content, with Simmental cows consistently producing milk with significantly higher fat percentages than their Holstein counterparts. On the other hand, protein content did not display any significant difference between the two breeds. However, Holstein milk was marked by a higher level of acidity, a finding that could have implications for certain dairy products. Additionally, this study highlights the critical role of environmental factors, such as topography, pasture quality, and the stage of lactation, in shaping milk composition. Notably, higher physicochemical values were observed in areas characterized by extensive and well-managed pastureland, indicating that these environmental conditions are conducive to enhancing certain milk qualities. While the research did not identify substantial breed-specific differences in mineral content, it did observe that mineral levels were influenced by local relief and geographical conditions. These findings contribute significantly to understanding breed-specific milk characteristics within the Dukagjin region, providing invaluable insights for dairy farmers who aim to optimize milk production and quality through strategic breed selection and effective environmental management practices.

Keywords: Holstein, minerals, physicochemical properties, Simmental

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INTRODUCTION

Dairy farming is vital to agricultural sustainability in Kosovo, particularly in the Dukagjin Plain region. The region's farmers rely heavily on the dairy sector for economic stability, predominantly raising cows of the Simmental and Holstein breeds. While a significant body of literature exists on dairy production, it mainly focuses on widely recognized milk quality parameters, such as somatic cell count, total bacterial count, and general milk classification systems (Khan et al. 2014). These parameters are critical indicators of milk hygiene and overall quality. However, there remains a notable gap in the local literature concerning the influence of specific cow breeds on the physicochemical properties of milk. These properties, which include fat and protein content, acidity, and mineral composition, are essential determinants of milk quality and have a direct impact on the economic viability of dairy farming (Agricultural Institute of Kosovo, Peja). The term "freshness", often used in broader contexts, typically refers to the sensory and microbiological qualities of milk, which can degrade over time due to bacterial activity and chemical changes.

Globally, studies have explored various aspects of milk composition, revealing significant breed-specific differences that can underlay breeding decisions and management practices. However, these findings have not been adequately translated to the context of Kosovo, where environmental factors, agricultural policies, and farming practices differ markedly from those in more extensively studied regions (Bytyqi et al. 2015, Kastrati et al. 2022). For instance, a comparison of milk production between Kosovo and Austria (Table 1) highlights that Austrian cows yield significantly more milk, a difference attributed mainly to Austria's advantageous relief and supportive dairy policies (Food and Veterinary Agency, 2023). Austria was selected as a reference point due to its proximity, its reputation as a benchmark for high dairy production standards, and shared environmental characteristics, such as mountainous regions and pastureland. This makes Austria particularly relevant for examining the potential influence of agricultural practices

Table 1

Variations in milk production between the identical genotypes (breeds) managed in Kosovo and Austria

	Production in Kosovo	Production in Austria	Differences	
Breed	Milk (kg day^{-1})	Milk (kg day^{-1})	Milk (kg day^{-1})	(%)
Brown Swiss	12.33	15.63	3.30	-21.11
Tyrol Grey	18.92	26.67	7.95	-29.06
Black Holstein	17.85	21.26	3.41	-16.04
Simmental	17.64	22.14	4.50	-20.33

and policies. The stark differences between the two countries further underscore the need for localized research that considers the unique environmental and agricultural conditions of the Dukagjin region.

Despite the evident importance of breed selection in optimizing milk production, local studies have focused primarily on quantifying milk yield without delving into the comparative analysis of milk's physicochemical properties across different breeds (Aliu et al. 2017). This oversight leaves farmers without critical information that could enhance their productivity and profitability. The most common breed in the Dukagjin region, the Simmental cow, is favored for its versatility, offering substantial yields of milk and meat and raw materials for cheese, yogurt, and whey production. However, the lack of detailed, breed-specific studies leaves a gap in the understanding how these breeds perform under the specific environmental conditions of the Dukagjin Plain.

This study aims to fill this gap by investigating milk's physicochemical and mineral properties from Simmental and Holstein cows in the Dukagjin region. By comparing these properties across breeds, the research seeks to provide farmers with actionable insights that can improve the quality and quantity of their milk production. Additionally, this study aims to identify the most suitable breed for the region, thereby supporting farmers in achieving greater economic sustainability and higher milk quality.

MATERIAL AND METHODS

Study area and sample collection

This study was conducted in five municipalities within the Dukagjin Plain region of Kosovo: Peja, Istog, Klina, Deçan, and Junik. These municipalities were selected because of their significant involvement in dairy farming, with a total cattle population of 77,720 across the region (Table 2) (Agricultural Institute of Kosovo, Peja; Business registration agency in Kosovo). The milk samples analyzed in this study were obtained from Holstein and

Table 2

Number of cattle in selected municipalities of the Dukagjin plain region

Municipalities	Number of cattle
Peja	25.869
Klina	23.869
Istog	18.908
Junik	650
Decan	8424
Total	77.720

Data source: Food and Veterinary Agency

Simmental cows on farms registered in the Kosovo business registry (Business Registration Agency in Kosovo). The farms were randomly selected within each municipality to ensure a representative sample.

Sampling procedure

Milk samples were collected between March and July 2023. Each farm provided samples twice a month, resulting in ten samples per farm over the five-month study period. A total volume of 150 ml of milk was collected for each sample, ensuring adequate quantity for all necessary analyses (Khan et al. 2014, Shkodra et al. 2020). The samples were stored immediately in a manual lactofreezer at 4°C to maintain their original quality during transport and storage (Rexhepi et al. 2018, Kastrati et al. 2022).

Laboratory analysis

The physicochemical properties of the milk, including pH, density, lactose, fat content, protein content, dry matter, conductivity, casein, fatty matter, acidity, ash content, freezing point, and lactic acid content, were analyzed using a MilkoScan FT1 device (Demi et al. 2021). This device employs a Fourier Transform Infrared (FTIR) technology, allowing for rapid and precise analysis of milk composition and detecting any abnormalities (Bytyqi et al. 2015).

Mineral content, specifically concentrations of calcium (Ca), potassium (K), magnesium (Mg), and sodium (Na), was determined using Microwave Plasma Atomic Emission Spectroscopy (MP-AES) (Ministry of Agriculture, Forestry and Rural Development. 2023). The MP-AES is a state-of-the-art technology that accurately quantifies mineral concentrations in milk samples.

Data handling and analysis

The data obtained from the analyses were subjected to statistical evaluation to assess the influence of a cow's breed (Holstein vs. Simmental) on the milk's physicochemical properties and mineral content. The results were analyzed to determine significant differences between the breeds and to understand the impact of environmental and management factors on milk quality.

RESULTS AND DISCUSSIONS

The results of the physicochemical analyses conducted over various periods provide a clear overview of the milk quality from different municipalities. These results are presented in tables that capture the periods in milk pro-

duction as well as the physicochemical properties and mineral content of milk. Some samples showed a positive alcohol test, indicating that Milkoscan FT1 could not test these, and such cases have been duly noted.

Physicochemical analysis
First period (March 15-28)

Table 3

The first period of physicochemical analysis, March 15-28

Municipality	Peja		Klina		Istog		Junik		Decan	
Parameters	HF	SI	HF	SI	HF	SI	HF	SI	HF	SI
pH	6.79	6.94	6.89	7.01	6.91	6.73	6.86	6.85	6.92	6.68
Density (g/cm^3)	1.0291	1.0274	1.0299	1.0284	1.303	1.0281	1.0297	1.0301	1.0279	1.0283
Lactose (%)	4.86	4.4	4.45	3.50	4.41	4.71	4.41	3.45	4.02	3.88
Fat (%)	1.61	3.32	1.71	3.29	2.01	2.75	3.04	3.06	2.55	2.75
Protein (%)	3.16	3.18	3.50	2.50	3.46	3.05	3.52	2.80	3.80	3.70
TS (%)	10.3	11.4	10.51	9.41	10.52	11.55	11.91	9.41	12.3	11.21
Cond	4736	4715	5341	6322	5012	5470	5115	3951	5841	6246
SNF (%)	8.69	8.08	8.80	6.12	8.51	8.80	8.87	6.35	9.75	8.46
°SH	6.76	6.67	6.85	6.53	6.81	6.58	6.97	6.65	6.81	6.89
Ashes (%)	0.68	0.69	0.60	0.61	0.64	0.66	0.69	0.67	0.60	0.65
Freezing Point (°C)	0.504	0.490	0.487	0.399	0.418	0.493	0.473	0.545	0.489	0.456
Casein (%)	2.52	2.55	2.83	2.00	2.76	2.44	2.85	2.24	3.04	2.96
Lactic ac. (%)	0.134	0.139	0.141	0.131	0.167	0.163	0.174	0.159	0.166	0.151

The fat percentage is notably higher in milk from the Simmental (SI) breed across all municipalities. In Peja, a significant difference is observed, with Holstein (HF) milk containing only 1.61% fat, while Simmental milk has 3.32% of fat. These findings align with previous studies that reported higher fat content in Simmental milk compared to Holstein, indicating breed-specific differences in milk composition (Khastayeva et al. 2021, Koknaroglu et al. 2021, Nusupov et al. 2021, Strączek et al. 2021).

Conversely, the protein content is generally higher in Holstein milk, with the most significant difference noted in Klina, where Holstein milk contains 3.5% protein compared to 2.5% in Simmental milk. This observation is consistent with findings from Lim et al. (2020) and Rodriguez et al. (1997), who also noted that Holstein milk tends to have higher protein levels than that of other breeds.

Regarding the ash content, milk from Simmental dairy cows exhibit higher levels, particularly in Decan, where the ash content is 0.65% in Simmental compared to 0.6% in Holstein. This is consistent with the findings of Chitchyan and Grigoryan (2016) and Hoffman and Taysom (2005), who

found that a breed and nutrition significantly influence the ash content in milk.

Second period (April 15-30)

Table 4

The second period of physicochemical analysis is April 15-30

Municipality	Peja		Klina		Istog		Junik		Decan	
Parameters	HF	SI	HF	SI	HF	SI	HF	SI	HF	SI
pH	6.86	6.70	6.86	7.08	6.66	6.62	6.67	6.65	6.72	6.88
Density (g/cm^{-3})	1.0301	1.0280	1.0285	1.0291	1.310	1.0291	1.0297	1.0307	1.0299	1.0296
Lactose (%)	4.93	4.7	4.50	3.77	4.81	4.75	4.49	/	4.70	4.00
Fat (%)	2.01	3.52	1.90	3.08	2.20	2.80	3.13	/	2.70	2.83
Protein (%)	3.19	3.78	3.54	2.58	3.54	3.10	3.57	/	3.65	3.80
TS (%)	10.7	11.6	10.7	9.20	10.70	11.60	12.0	9.30	12.50	11.3
Cond	4766	4719	5355	6332	5022	5680	5128	3068	5101	6046
SNF (%)	8.69	8.08	8.80	6.12	8.51	8.80	8.87	/	9.80	8.46
°SH	6.98	6.83	6.92	6.88	6.74	6.78	6.77	6.79	6.85	6.83
Ashes (%)	0.62	0.64	0.65	0.67	0.63	0.69	0.65	0.63	0.67	0.68
Freezing Point (°C)	0.534	0.530	0.497	0.391	0.518	0.483	0.494	/	0.475	0.436
Casein (%)	2.47	2.90	2.75	1.81	2.21	2.37	2.81	/	2.92	2.95
Lactic ac. (%)	0.119	0.155	0.151	0.101	0.163	0.153	0.171	/	0.149	0.146

The physicochemical analysis of milk from both Holstein and Simmental breeds shows noteworthy trends that align with findings from previous studies reported in the literature.

Fat content: The fat percentage in Simmental milk consistently surpasses that of Holstein milk across various municipalities, notably in Peja, where Simmental milk contains 3.52% fat compared to 2.01% in Holstein. This observation is consistent with the findings of Walsh et al. (2008), who noted that Simmental breeds typically yield higher fat content due to their genetics and feeding regimes. Similarly, Adriaens et al. (2023), Toušová et al. (2014) reported that breed differences in the fat content can be attributed to the proportion of concentrate feed in the diet and genetic predisposition to fat synthesis in the udder.

Protein levels: The protein content in Holstein milk is notably higher, especially in Klina, where it is 3.54% in Holstein compared to 2.58% in Simmental. This is supported by the results of other studies (Ignatieva and Aizatov 2012, Ignatieva and Nemtseva 2020), which indicated that Holstein cows tend to produce milk with higher protein concentrations due to selective breeding for milk yield and quality. The superior protein levels in Holstein milk could also be linked to their nutritional management and milking practices (Kalscheur et al. 2006).

Ash content: The trend towards a higher ash content in Simmental milk aligns with the findings by Hoffman and Taysom (2005), who suggested that the mineral composition of milk is influenced by breed and dietary factors. Elevated ash levels can indicate differences in the dietary mineral intake and metabolism between the two breeds.

Lactose and SNF: The lactose and solid-not-fat (SNF) percentages also reflect the breed differences. Holstein milk generally exhibits higher lactose content, which is crucial for dairy product manufacturing (Nayak, n.d.). The observed SNF percentage is particularly significant in Klina, suggesting that nutritional strategies could be optimized to enhance these parameters.

Freezing point: The freezing point of milk is a critical indicator of its quality and composition. A lower freezing point, as observed in Simmental milk, suggests a higher concentration of total solids, including proteins and minerals. In contrast, milk from Holstein cows exhibits a higher lactose content, which can elevate osmotic pressure and subsequently affect freezing point values. The higher lactose levels in Holstein milk are likely due to the breed's genetic predisposition toward higher milk volume production, which is correlated with greater synthesis of lactose, a key determinant of milk yield. Pesce et al. (2016) investigated the factors influencing milk's freezing point and found that both breed-specific traits and nutritional management are significant contributors. Their study demonstrated that breeds producing higher volumes of milk, such as Holstein, tend to exhibit a marginally higher freezing point due to the dilution of solids in the milk matrix. Additionally,

Third period (May 15-30)

Table 5

The third period of physicochemical analysis, May 15-30

Municipality	Peja		Klina		Istog		Junik		Decan	
Parameters	HF	SI	HF	SI	HF	SI	HF	SI	HF	SI
pH	6.82	6.71	6.89	6.79	7.02	6.91	6.75	6.81	6.81	6.78
Density (g/cm^{-3})	1.0304	1.0291	1.0219	1.0251	1.0211	1.0256	1.0250	1.0298	1.0296	1.0306
Lactose (%)	5.12	4.96	4.65	3.98	4.91	4.97	4.78	4.66	4.97	4.86
Fat (%)	2.97	3.14	2.18	3.69	1.65	2.44	2.02	2.74	1.92	3.24
Protein (%)	3.69	3.95	3.68	4.04	4.06	3.93	3.91	3.60	3.86	3.55
TS (%)	12.36	12.59	10.87	12.34	11.9	12.34	11.60	11.66	11.89	12.20
Cond	5611	4948	4796	6557	5767	4809	5266	5319	4901	6216
SNF (%)	9.39	9.45	8.69	8.65	10.25	9.90	9.58	8.92	9.97	8.98
°SH	6.59	6.90	6.82	6.72	6.91	6.74	7.00	6.91	6.58	6.52
Ashes (%)	0.57	0.71	0.68	0.59	0.61	0.66	0.69	0.58	0.67	0.64
Freezing Point (°C)	0.513	0.501	0.478	0.491	0.517	0.509	0.493	0.512	0.510	0.473
Casein (%)	2.95	3.10	2.94	3.23	3.24	3.144	2.98	2.89	3.01	2.88
Lactic ac. (%)	0.141	0.153	0.151	0.136	0.162	0.149	0.138	0.145	0.138	0.131

nutritional factors like feed composition and mineral balance play a role by modulating the osmotic concentration of milk, directly impacting its freezing properties. For instance, diets rich in energy and balanced minerals were found to stabilize the freezing point, while deficiencies or imbalances led to variations that underscored the interaction between feed and breed physiology.

A comparison of fat, protein, and ash content determined in our study with other authors' findings provides broader context and supports our observations.

Fat content: The results show a significant difference in the fat content between the Simmental and Holstein breeds, with Simmental consistently having higher values. For instance, in Klina, Simmental milk has a fat content of 3.69% compared to 2.18% in Holstein milk. Similar results have been observed in studies such as by Brito et al. (2021), where genetic selection for milk composition led to notable differences in the fat content between breeds. Simmental cows are often preferred for their higher milk fat percentage, which aligns with their traditional use in dual-purpose (meat and milk) production systems. These findings underscore the breed's ability to produce milk with higher fat content, especially in more extensive systems or favorable climatic conditions (Linn 1988).

Protein content: Regarding the protein content, the trend observed in this study suggests that both breeds had elevated protein percentages in the third period, likely due to favorable weather and feeding conditions. The protein content in Simmental milk in Klina reached 4.04%, compared to 3.68% in Holstein. These results are consistent with findings by Szepe et al. (2021), who reported that the protein content in milk is influenced by genetic factors and environmental conditions. Studies such as by Król et al. (2008) have also noted that Simmental cattle tend to produce milk with higher protein content, which is advantageous for cheese production, especially in regions where local feeding practices enhance milk quality.

Ash content: The ash content (a measure of mineral concentration) also shows notable differences. In Peja, Simmental milk had an ash content of 0.71%, compared to 0.57% in Holstein milk. This observation is in line with findings from studies like that of Linn (1988), who noted that milk composition, including the ash content, is impacted by a breed, diet, and environmental conditions. The higher mineral content in Simmental milk may be due to their grazing habits and feed types, which influence the mineral uptake. Additionally, Amalfitano et al. (2024) highlighted that the mineral content of milk plays a critical role in improving the nutritional value of dairy products, particularly in traditional cheese-making.

Fourth period (June 15-30)

Table 6

The fourth period of physicochemical analysis, June 15-30

Municipality	Peja		Klina		Istog		Junik		Decan	
Parameters	HF	SI	HF	SI	HF	SI	HF	SI	HF	SI
pH	6.77	6.51	6.8	6.85	6.92	6.87	6.69	6.62	6.84	6.78
Density (g/cm^3)	1.0304	1.031	1.029	1.0291	1.0296	1.0303	1.0310	1.0298	1.0308	1.030
Lactose (%)	5.16	4.90	4.22	3.50	/	4.86	4.65	4.81	4.89	4.60
Fat (%)	2.24	3.48	2.19	4.6	/	3.24	1.72	1.98	1.65	2.60
Protein (%)	3.19	3.65	3.53	4.19	/	2.98	3.64	2.89	3.62	3.12
TS (%)	11.2	12.9	10.7	12.7	11.4	12.14	9.90	9.90	11.12	11.80
Cond	4662	4844	5076	6957	6917	5899	5736	5529	5726	5988
SNF (%)	8.96	9.42	8.51	8.10	/	8.90	8.18	7.92	9.46	8.15
°SH	6.84	6.7	6.92	6.88	7.1	6.94	6.81	6.75	6.90	6.83
Ashes (%)	0.67	0.65	0.64	0.67	0.64	0.63	0.61	0.62	0.63	0.64
Freezing Point (°C)	0.573	0.556	0.458	0.413	/	0.513	0.513	0.500	0.519	0.483
Casein (%)	2.41	2.81	2.65	3.10	/	2.4	2.95	2.31	2.89	2.49
Lactic ac. (%)	0.125	0.160	0.136	0.144	/	0.163	0.172	0.151	0.157	0.153

Fat content: The results from the fourth period, particularly in Klina, show a significant disparity in the fat content between the Simmental (SI) and Holstein Friesian (HF) breeds, with Simmental milk exhibiting a notably higher fat percentage (4.6% in SI vs. 2.19% in HF). This trend mirrors previous findings where Simmental cows consistently produce milk with higher fat content. Such variations in the fat content between breeds are supported by research from Ozhan et al. (2015), who note that Simmental cattle, known for their dual-purpose use (milk and meat), tend to produce higher-fat milk compared to dairy-focused breeds like Holstein. The fat content in milk can also be influenced by feeding practices and environmental conditions.

Protein content: In terms of the protein content, the analysis shows that Simmental milk continues to outperform Holstein milk, particularly in Klina, where Simmental milk has a protein percentage of 4.19%, compared to 3.53% in Holstein milk. This is consistent with the findings by Bigler (2001) and Mlynek et al. (2018), who noted that Simmental cattle often produce milk with higher protein content, beneficial for cheese production. The higher protein content during this period may be attributed to the favorable grazing conditions in June, which can enhance milk quality.

Ash content: As observed in earlier periods, the ash content, representing the mineral concentration in milk, remains higher in Simmental milk. This difference is particularly noted in Peja and Klina, where Simmental milk has ash percentages of 0.67% in both cases, compared to 0.64%

in Holstein milk. These findings align with previous studies showing breed-related differences in milk composition. Khastayeva et al. (2021) found that Simmental cows tend to have higher mineral content in their milk compared to Holstein cows, with variations influenced by lactation stages and seasonal factors. Moreover, Koknaroglu et al. (2021) highlighted the superior nutritional composition of Simmental milk, which plays a crucial role in the profitability and quality of dairy products. Lim et al. (2020) also emphasize that milk composition, particularly in terms of the mineral and ash content, can significantly differ between breeds and can impact the quality of products such as cheese.

Other parameters: During this period, the casein content in Simmental milk was notably higher than in Holstein milk, with concentrations reaching 3.10% in Klina compared to 2.65% in Holstein milk. Simmental milk also exhibited a slightly higher lactic acid concentration, which suggests better fermentation properties, potentially beneficial for dairy processing. These findings are supported by Khastayeva et al. (2021), who similarly reported qualitative differences in milk components between Simmental and Holstein cows across different seasons, highlighting superior protein content in Simmental milk, which is advantageous for cheese production and other dairy products.

Fifth period (July 15-30)

Table 7

The fifth period of physicochemical analysis, July 15-30

Municipality	Peja		Klina		Istog		Junik		Decan	
Parameters	HF	SI	HF	SI	HF	SI	HF	SI	HF	SI
pH	6.67	6.76	6.98	6.85	6.92	7.01	6.69	6.59	6.94	6.88
Density (g/cm^3)	1.0254	1.021	1.025	1.0301	1.0291	1.0273	1.0290	1.0268	1.0262	1.030
Lactose (%)	5.10	4.95	4.49	3.84	4.8	4.94	4.68	4.79	4.65	4.53
Fat (%)	2.75	3.54	2.36	3.09	1.43	3.54	2.04	2.98	1.84	3.25
Protein (%)	3.59	3.75	3.60	4.14	3.86	3.43	3.71	2.86	3.42	3.05
TS (%)	12.1	12.79	10.87	11.54	10.9	12.64	10.82	11.60	11.4	11.80
Cond	4712	4848	4596	6157	5717	4919	5136	5529	4926	6188
SNF (%)	9.35	9.25	8.51	8.45	9.47	9.10	8.78	8.62	9.56	8.55
°SH	6.74	6.85	6.72	6.98	7.01	6.84	6.89	6.71	6.91	6.82
Ashes (%)	0.61	0.71	0.64	0.62	0.59	0.63	0.60	0.69	0.67	0.66
Freezing Point (°C)	0.543	0.416	0.518	0.413	0.540	0.483	0.513	0.478	0.480	0.473
Casein (%)	2.87	3.00	2.95	3.32	3.08	2.744	2.84	2.26	2.63	2.37
Lactic ac.(%)	0.115	0.169	0.146	0.153	0.162	0.163	0.152	0.131	0.127	0.143

Fat content: The trend continues with Simmental milk showing a higher fat content, especially in Istog, where it reaches 3.54% compared to only 1.43% in Holstein milk. This finding aligns with the research by Adriaens et al. (2023), who discussed genetic and dietary factors influencing milk composition across different dairy breeds. Their study emphasized that the breed's genetic predisposition plays a significant role in the fat content of milk, supporting the results observed in this study.

Protein content: The protein content remains higher in Holstein milk across most municipalities, with a significant difference noted in Junik (3.71% in Holstein vs. 2.86% in Simmental). Previous studies by Brito et al. (2021) corroborate this observation, indicating that Holstein cows generally produce milk with higher protein concentrations. This protein richness is particularly desirable for cheese production, as highlighted by Cañeque et al. (2021), who noted that the protein profile of milk significantly impacts its suitability for dairy products. The consistent findings across these studies underscore the importance of breed selection in optimizing the milk protein content for commercial dairy operations.

Ash content: The ash content is predominantly higher in Holstein milk, with the most considerable difference observed in Peja (0.71% in Simmental vs. 0.61% in Holstein). The research by Amalfitano et al. (2024) supports the notion that Holstein milk typically has greater mineral content, contributing to higher ash levels. Their analysis indicated that mineral profiles can vary significantly across breeds, further influencing overall milk quality and nutritional value. This higher mineral content in Holstein milk may provide additional health benefits for consumers, reinforcing the breed's preference in certain markets.

Lactose and freezing point: Lactose levels were found to be higher in Holstein milk (average of 4.97%) compared to Simmental milk (average of 4.71%). This finding is consistent with the observations of Rodriguez et al. (1997), who reported that lactose content can vary significantly between breeds due to differences in metabolism and nutritional requirements. Moreover, the freezing point of milk serves as an indicator of its quality, with Holstein milk exhibiting slightly lower freezing points on average. This suggests compositional differences that could affect processing, as noted by Pesce et al. (2016) in their work on the freezing point of various milk types. These insights highlight the importance of breed characteristics in determining the quality and usability of milk in the dairy industry.

Mineral analysis
First period (February 28)

Table 8

Results of minerals in the first period, February 28

Municipal	Minerals	Ca (mg l^{-1})	K (mg l^{-1})	Mg (mg l^{-1})	Na (mg l^{-1})
Peja	HF	1353.4	1392.8	86.9	1482.4
	SI	1260.3	1350.9	92.8	626.0
Klina	HF	988.7	982.8	86.4	1214.2
	SI	1054.1	968.4	93.5	1669.0
Istog	HF	1191.8	930.2	86.9	1481.3
	SI	1187.4	1287.5	90.4	613.5
Junik	HF	1057.3	1013.6	90.1	1054.6
	SI	1089.5	1007.3	91.9	708.3
Decan	HF	1186.5	1104.7	93.5	985.6
	SI	1180.4	1164.4	88.6	812.0

The results of this study reveal notable differences in the milk composition and production across various dairy breeds, aligning with findings from previous research. Adriaens et al. (2023) emphasized how daily milk yield can serve as a proxy for resilience among different dairy breeds. This is particularly relevant given that our data indicate distinct variances in yield and composition linked to genetic factors.

Furthermore, the detailed mineral profile examined by Amalfitano et al. (2024) in milk from various breeds supports our findings that breed-specific characteristics significantly influence mineral content. Their study highlights the efficiency of mineral recovery in cheese production, which may parallel our observations regarding the nutritional quality of milk from different breeds.

The genetic selection for high-yielding dairy cattle has been a topic of considerable interest, as discussed by Brito et al. (2021). Their review argues for sustainable farming practices amid a changing environment, which echoes our recommendations for optimizing breeding strategies to enhance both yield and sustainability in dairy production.

Additionally, the research conducted by Cabezas-Garcia et al. (2021) reiterates the relationship between the fat-to-protein ratio in milk and the energy balance in dairy cows, particularly during different lactation stages. Our results suggest similar trends, indicating that these factors are crucial for understanding the overall health and productivity of dairy herds.

Comparative studies, such as that by Lim et al. (2020), demonstrate variations in milk composition during early lactation between Jersey and Holstein cows, which resonates with our findings of breed-specific differences

in milk quality. Such variations can significantly impact both consumer preferences and dairy processing outcomes.

Moreover, the performance analysis presented by Koknaroglu et al. (2021) underlines the importance of understanding the economic implications of a breed choice in dairy farming. Our results highlight that the production efficiencies of Holstein versus Simmental breeds can affect profitability, suggesting that economic factors should be considered alongside production metrics.

The impact of dietary factors on milk composition has also been documented extensively. For instance, Rodriguez et al. (1997) investigated how the degradability of dietary protein affects milk components. This aligns with our results that highlight the role of nutritional management in optimizing milk quality.

In terms of seasonal variations in milk quality, Khastayeva et al. (2021) reported significant changes in the quality of milk from Simmental and Holstein cows throughout different lactation periods, which further supports our findings of fluctuating quality parameters tied to lactation stages.

Second period (July 30)

Table 9

Results of minerals in the second period. July 30

Municipal	Minerals	Ca (mg l^{-1})	K (mg l^{-1})	Mg (mg l^{-1})	Na (mg l^{-1})
Peja	HF	1304.6	1428.1	89.2	1317.5
	SI	1203.7	981.6	89.3	657.4
Klina	HF	1037.9	1643.6	74.1	834.3
	SI	943.5	1046.7	58.2	1112.4
Istog	HF	1210.3	1184.1	95.2	794.5
	SI	1034.5	1648.3	81.0	526.7
Junik	HF	1258.6	1711.4	93.4	661.8
	SI	1337.4	1183.6	92.1	874.6
Decan	HF	1187.3	1317.5	83.5	865.3
	SI	978.8	1094.1	78.3	913.2

Table 9 presents the mineral concentrations in the milk from Holstein Friesian (HF) and Simmental (SI) cows across different municipalities in Kosovo, focusing on calcium (Ca), potassium (K), magnesium (Mg), and sodium (Na).

Calcium (Ca) concentration: The results indicate a clear trend of higher calcium concentrations in the milk of Holstein cows compared to Simmental cows across all municipalities, with the exception of Klina. This aligns with

findings from previous studies which suggest that breed differences significantly impact mineral content in milk. For example, Brito et al. (2021) noted that high-yielding dairy breeds, such as Holsteins, typically exhibit enhanced milk mineral content, particularly calcium.

Moreover, the municipalities of Peja and Junik recorded the highest calcium levels, which could be attributed to the quality of the grasslands in these areas. This is consistent with the findings of Stergiadis et al. (2021), who reported that grazing management practices influence mineral concentrations in milk. The high availability of calcium in the pastures could directly enhance the mineral profile of milk produced by cows grazing in these regions.

Potassium (K) concentration: The potassium concentrations varied among municipalities, with Holstein cows' milk showing generally higher levels than that from Simmental cows. The difference in potassium levels could reflect dietary intake, with Holsteins potentially receiving feed that is richer in potassium. This finding corroborates the work of Kalscheur et al. (2006), who emphasized that dietary composition plays a crucial role in the mineral content of milk.

Magnesium (Mg) concentration: In terms of magnesium, the results demonstrate slight variations but are less pronounced than those observed for calcium and potassium. While both breeds maintained similar magnesium levels, the influence of pasture quality and composition may still play a role. Research has shown that magnesium availability in grazing systems can vary based on soil quality and fertilization practices (Cabezas-Garcia et al. 2021).

Sodium (Na) concentration: Sodium levels showed significant variability across the municipalities, particularly in the Simmental breed. In many cases, Simmental cows exhibited lower sodium concentrations in milk, which could be linked to dietary differences or hydration levels. This observation aligns with the findings of Ignatieva and Nemtseva (2020), who suggested that environmental factors and feeding practices can lead to disparities in the sodium content in milk.

CONCLUSIONS

This study provides a comprehensive overview of milk production and quality in Kosovo, offering specific insights into breed performance and regional influences. Our key findings are as follows:

Breed distribution: The Simmental breed is more prevalent in Kosovo that the Holstein one.

Milk production: Holstein cows exhibit superior milk production compared to Simmental cows, which demonstrate significantly lower yields.

Milk quality: Although Simmental milk has a higher fat content, protein levels vary without a consistent difference between the two breeds.

Regional impact: The geographical landscape significantly affects milk quality, with the municipalities of Peja and Istog showing markedly higher values than other regions.

Lactation influence: The physicochemical properties of milk improve as lactation progresses, highlighting the impact of the lactation stage on milk quality and composition.

Mineral content: While no significant differences in mineral content exist between breeds, the topography and location of municipalities, particularly Istog and Peja, influence mineral levels, with these areas exhibiting higher concentrations.

These findings underscore the importance of breed selection, regional factors, and lactation stages in optimizing milk production and quality in Kosovo. By analyzing these factors, dairy farmers and stakeholders can tailor practices to further optimize milk production and quality in line with regional advantages.

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Author contributions

S.M., A.E. – conceptualization; S.M., V.G. – formal analysis; S.M., A.E. – methodology; S.M. – investigation; A.E., V.G. – visualization; S.M., A.E. – writing, original draft preparation; S.M., A.E., V.G. – writing, review, and editing. All authors have read and agreed to the published version of the manuscript.

Conflicts of interest

The authors declare no conflicts of interest. They confirm that they have no professional or financial affiliations that could influence the content of the manuscript submitted to the Editorial Board.

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