https://doi.org/10.61308/QWBF4687

Quality of cow's milk as a raw material in the dairy industry from the Pelagonian region in North Macedonia

Gordana Dimitrovska*, Morena Pandovska, Borche Makarijoski and Elena Joshevska
Faculty of Biotechnical Sciences-Bitola, „St. Kliment Ohridski" University-Bitola, North Macedonia
*Corresponding author: gordana.dimitrovska@uklo.edu.mk

Citation: Dimitrovska, G., Pandovska, M., Makarijoski, B. & Joshevska, E. (2024). Quality of cow's milk as a raw material in the dairy industry from the Pelagonian region in North Macedonia. *Bulgarian Journal of Animal Husbandry, 61*(3), 65-72.

Abstract: This scientific work provides a comparison and analysis of the quality and hygiene requirements of raw cow's milk obtained from individual producers of large and small farms in three regions of Pelagonia in accordance with the Rulebook on requirements for quality, safety and hygiene of milk. The examinations include analysis of the parameters of the chemical composition, determination of the number of somatic cells and total number of bacteria from milk samples taken throughout the year from small and large farms. The best results ($p<0.05$) for the protein content are observed in the milk coming from small and large farms from the Southern part of the Pelagonia region, compared to the Northern part of the Pelagonia region and Prilep region. The amount of dry fat-free matter in the milk from small farms in all three regions did not show a statistically significant difference ($p<0.05$). The results for the lactose content of milk from all three examined regions are within the limits of the Rulebook for raw milk. A significant difference ($p<0.01$) was found for the content of somatic cells in small farms. It is noteworthy that small farms deviate significantly from the safety and hygiene requirements outlined in the Rulebook, primarily due to the hygiene practices concerning dairy cows. The results obtained will be valuable for the dairy industry, as they will identify weaknesses among domestic producers. Professional services will implement measures and activities to help farmers meet EU standards in milk production. Additionally, these findings will provide a significant basis for establishing strategies in this agricultural sector.

Keywords: cow's milk; quality; hygiene; regional settlement

INTRODUCTION

Milk, a staple food consumed daily by millions worldwide, is subject to rigorous statutory regulations to ensure its quality. Cow's milk is officially defined as "the unaltered product of the udder, obtained through regular, complete, and uninterrupted milking of one or more cows." When milk from other mammals is marketed, it must be clearly labeled with the name of the mammal it originates from, such as sheep's milk or goat's milk. These regulations are designed to guarantee that milk comes from properly fed and managed animals, and in many cases, it must be thoroughly mixed without additives or alterations.

The quality of raw milk is determined by several factors, including its chemical composition, physical properties, and hygienic quality (Antunac et al., 1997). Given its nutritional significance and widespread consumption, it is crucial to implement stringent measures to enhance milk quality. Key aspects of milk quality include its composition and health-hygienic standards, both of which are essential for its nutritional, technological, and commercial value.

Recent scientific advancements have further emphasized the importance of maintaining high standards in milk production. Modern quality assessment practices focus on ensuring milk's nutritional content and safety, reflecting the latest understanding of dairy science and consumer health. Research has highlighted that genuine milk quality cannot be assured without meeting stringent hygienic standards, as these are integral to preventing contamination and ensuring consumer safety (Havranek and Rupić, 2003; Brown & Green, 2021).

With the adoption of EU Directive 92/46 and Regulation EC 04/853, higher standards for raw milk quality have been established across EU countries. These regulations assess raw milk based on its chemical composition, physical properties, hygienic quality, and the presence of inhibitory substances. The goal of these stringent criteria is to ensure that milk is safe for consumption and meets the high expectations of both the dairy industry and consumers (Rossi & Bertuzzi, 2022).

New research continues to underscore the significance of these measures. For instance, studies have shown that improved milking practices and enhanced feeding regimens for cows can significantly elevate the quality of milk produced. Advanced testing methods now allow for more precise monitoring of milk's composition and safety, further aligning production practices with regulatory requirements (Smith, Jones, & Williams, 2022; Patel & Singh, 2023). Research on the chemical composition and physical properties of high-quality milk has provided deeper insights into what constitutes superior milk (Zhao & Liu, 2023).

The quality of milk is a multifaceted attribute that involves comprehensive measures to ensure its safety, nutritional value, and suitability for various uses. As scientific research progresses, these standards are continually refined to meet the evolving needs of consumers and the dairy industry. Ensuring that milk producers adhere to these high standards is essential for maintaining public health and confidence in dairy products.

MATERIALS AND METHODS

For the study, raw milk from the Holstein-Friesian cattle breed will be utilized. Samples will be collected from farms of individual milk producers, extracted from bulk milk stored in lactofreezers at +4°C. These farms are located in three distinct regions of the Pelagonian area: The North Pelagonian Region (NPR), the South Pelagonian Region (SPR), and the Prilep Pelagonia Region (PPR). Sampling was conducted over the course of a year, involving eight farms operated by individual milk producers, including both small farms (up to 10 milking cows) and large farms (up to 60 milking cows).

Samples for chemical analysis will be taken every 48 hours during the year. Chemical analysis of the milk will involve testing for milk fat, proteins, total solids, solids-not-fat, and lactose, using the MILKOSCAN FT 120 instrument Microbiological analysis of raw milk will be conducted twice a month over the course of one year. The total bacterial count will be determined using the Bactocount method according to ISO 21187:2004. The total somatic cell count will be determined using the Fossomatic method according to ISO 13366 Part 2. According to the Regulation on special requirements for safety and hygiene and the manner and procedure for official controls of milk and dairy products (Official Gazette No. 26/2012), the total bacterial count should be up to 100,000/ml, while the total somatic cell count should be 400,000 cells/ml.

The statistical analysis of the obtained results from the conducted experiments, were interpreted by using variation-statistical methods, which are applied for scientific research purposes. Microsoft Excel package, was used for data processing and all data were tabulated and graphically presented. Using the special functions provided by this package, parameters such as the mean ($\overline{x}$), coefficient of variation (CV), and standard deviation (SD) were calculated. Statistical comparisons for significance between the tested milk samples was made using a t-test, which is also included in this package.

RESULTS AND DISCUSSION

Lactose is a milk sugar that is most commonly found in milk and is also involved in the production of various dairy products. The results for the content and dynamics of lactose from all examined regions are presented in Table 1 and Graph. 1.

The average values for lactose content in milk ranged from 4.14% to 4.47% for small farms and from 4.47% to 4.90% for large farms. A statistical analysis revealed a significant difference ($p < 0.05$) between both small and large farms, as well as between the NPR and SPR. The results for lactose content in milk from all three tested regions fall within the limits set by the Regulation for Raw Milk. According to different authors (Costa et al. 2019; Álvarez-Martin et al., 2022), the average lactose content should be in range from 4.4% to 5.6%, which aligns with our research findings.

LI et al. (2019) indicate that the lactation stage is a crucial factor responsible for differences in the composition and physicochemical properties of dairy cattle, including changes in lactose as a parameter of the chemical composition.

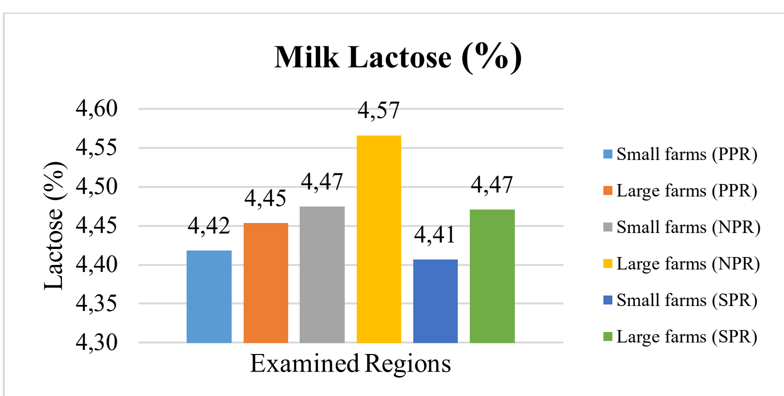
The content of the parameters of the non-fat dry matter in the milk samples from all examined regions is presented in Table 2 and Graph. 2. The average values of non-fat dry matter in milk range from 8.49% to 8.59% for small farms and from 8.63% to 8.81% for large farms across all three regions respectively. The lowest percentage of non-fat dry matter was observed in milk produced on small farms in the PPR (8.49%), while the highest was in milk from large farms in NPR (8.81%).

The quantity of non-fat dry matter in milk from small farms in all three regions showed no statistically significant difference ($p < 0.05$), as evidenced by the standard deviation ranging from 0.17 to 0.20 concerning differences between non-fat dry matter from large farms in SPR- 8.70.% and in NPR- 8.82%, which is statistically significant at a level of ($p < 0.05$).

Such differences are primarily attributed to differences in the genetic composition of cows,

Table 1. Percentage of lactose in milk samples in examined regions

Parameter	Lactose (%)					
Number (N)	13	13	13	13	13	13
Region	Small farms (PPR)	Large farms (PPR)	Small farms (NPR)	Large farms (NPR)	Small farms (SPR)	Large farms (SPR)
Mean	4.42	4.45	4.47	4.57	4.41	4.47
Standart Deviation	0.05	0.11	0.10	0.10	0.18	0.07
CV	1.20	2.41	2.18	2.12	4.01	1.49



Graphic 1. Percentage of lactose in milk samples in examined regions

the system and quality of nutrition, the health status of the animals, and climatic conditions. According to our Regulation for Raw Milk from 2011, cow's milk must have a minimum of 8.50% non-fat dry matter. All analyzed samples met this criteria according to the Regulation. Studies by various authors indicate that the chemical composition of milk, particularly when examining non-fat dry matter, is higher in cows originating from mountainous regions and hilly mountainous areas.

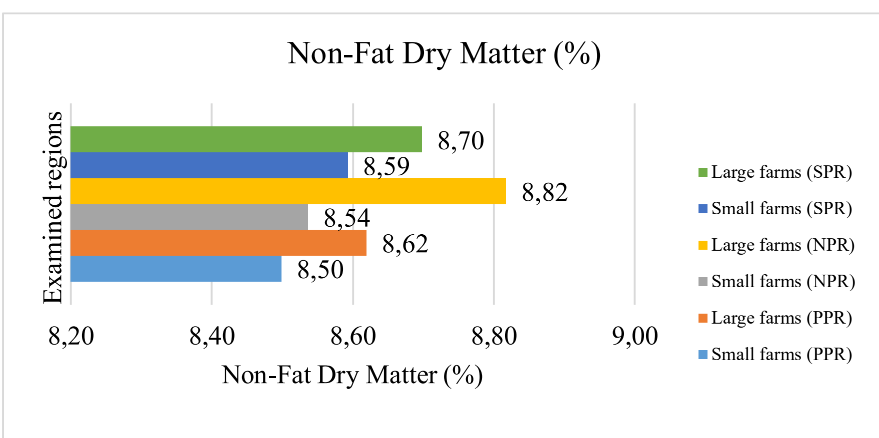
Our results are similar to those of Petrović et al. (2006), who conducted a study on the chemical composition and hygienic quality of cow's milk from ten collection points in Serbia. The authors found that the results for chemical composition among collection points do not differ significantly, and regarding non-fat dry matter results, they were determined to range from 8.34% to 8.98%, which is approximately similar to our values. This is most likely due to similar climatic conditions in both our and their studied areas.

Proteins are the most important component of the chemical composition of milk, playing a crucial role in its quality and in the process of milk processing into dairy products. The results from this region also indicate that the average protein content in milk from both small and large tested farms falls within the limits set by the Regulation for the quality of raw milk.

The average values for protein content in milk ranged from 3.10% to 3.16% for small farms and from 3.15% to 3.18% for large farms across all three regions, respectively (Table 3 and Graph. 3). When comparing large and small farms across all production lines in the tested regions, there are statistically significant differences at a level of ($p < 0.05$), which are likely due to differences

Table 2. Percentage of Non-fat dry matter in milk samples in examined regions

Parameter	Non-Fat Dry Matter (%)					
Number (N)	13	13	13	13	13	13
Region	Small farms (PPR)	Large farms (PPR)	Small farms (NPR)	Large farms (NPR)	Small farms (SPR)	Large farms (SPR)
Mean	8.50	8.62	8.54	8.82	8.59	8.70
Standart Deviation	0.11	0.07	0.18	0.19	0.20	0.18
CV	1.30	0.78	2.05	2.10	2.33	2.01



Graphic 2. Percentage of non-fat dry matter in milk samples in examined regions

in genetic composition, cow nutrition, their age, and lactation phase from the region where a higher average value was observed (Dürr et al., 2009; Bava et al., 2014; Noro et al., 2006; Auldist et al., 2010; O'Brien et al., 1999).

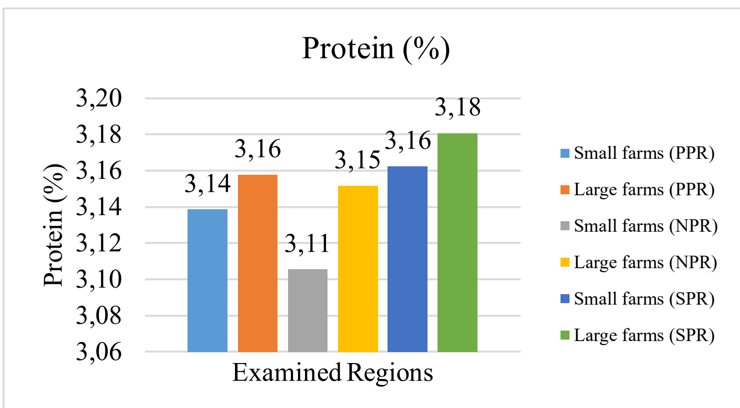
Milk fat, along with proteins, is the most important and variable component of the chemical composition of milk, influenced significantly by genetic and non-genetic factors.

Results for the dynamics of milk fat by regions are provided in Table 4 and Graph. 4.

Through analysis of all three regions, the lowest milk fat content was observed in milk from small farms in PPR (3.49%) and 3.65% in large

Table 3. Percentage of Protein in milk samples in examined regions

Parameter	Protein (%)					
Number (N)	13	13	13	13	13	13
Region	Small farms (PPR)	Large farms (PPR)	Small farms (NPR)	Large farms (NPR)	Small farms (SPR)	Large farms (SPR)
Mean	3.14	3.16	3.11	3.15	3.16	3.18
Standart Deviation	0.11	0.10	0.13	0.11	0.10	0.10
CV	3.47	3.14	4.34	3.41	3.25	3.01



Graphic 3. Percentage of protein in milk samples in examined regions

Table 4. Percentage of Milk fat in milk samples in examined regions

Parameter	Milk fat (%)					
Number (N)	13	13	13	13	13	13
Region	Small farms (PPR)	Large farms (PPR)	Small farms (NPR)	Large farms (NPR)	Small farms (SPR)	Large farms (SPR)
Mean	3.50	3.65	3.75	3.81	3.16	3.18
Standart Deviation	0.16	0.25	0.21	0.19	0.10	0.10
CV	4.46	6.76	5.70	5.00	3.25	3.01

farms in the same region compared to the other two. The best results ($p < 0.05$) were observed in milk originating from both small and large farms in SPR compared to the NPR and PPR. It is assumed that such differences, besides the different feeding practices, also arise from the climatic conditions in the different regions.

Variations in milk fat content are also a result of the genetic composition of the dairy herd, as well as the methods and hygiene of rearing. In the southern part of the tested region, farmers mainly rear high-yielding dairy cattle or their crossbreeds, whereas producers from the Prilep region rear Simmental breeds and their crossbreeds, whose fat content is lower by about 0.2% to 0.4% compared to East Friesian and Holstein breeds.

Dozet (1976) found that in mountainous regions, milk fat content in dairy cows ranges from 3.84% to 4.60% in hilly mountainous regions.

Bašič et al. (2012) conducted a study on the chemical composition of raw milk from 30 farms of varying sizes, from three regions (Eastern, Central, and Southern regions) in Croatia. Milk obtained from Holstein, Simmental, and native cows and their crossbreeds was analyzed. The average milk fat content in all analyzed samples was 4.14%. The lowest milk fat content was found in milk produced on large farms in the Eastern region (3.99%), while the highest (4.31%) was observed in milk from farms in the Southern region.

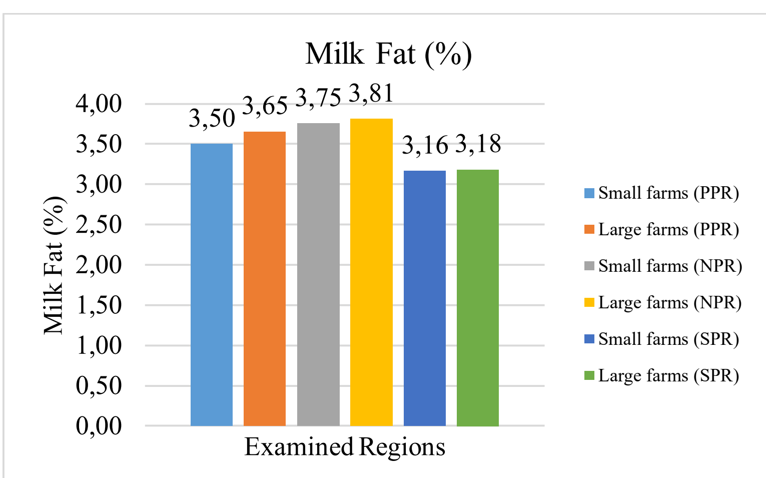
In the research by Marcondes et al. (2012) on the quality of raw milk in different production systems and their variations throughout the year from 934 dairy cows in the Southern, Central-Western, and Central regions of Brazil, seasonal variations were found with the highest fat content from May to August, i.e., 3.59% for the Southern region, 3.62% for the Central-Western region, and 3.61% for the Central region, which correlates with our findings, (Vargas-Bello-Pérez et al., 2014; Walton et al., 2021).

The obtained results from the farms in the tested regions of our country are in accordance with the current Regulation for raw milk, which stipulates that cow's milk should contain at least 3.2% milk fat. Consequently, all analyzed samples from all farms in the tested regions meet this legal criterion.

Results for somatic cell count (SCC/ml) in milk production from the tested farms in all three regions are presented in Table 5.

The results of the study show significant differences in the somatic cell count (SCC) and total bacterial count in milk from small and large farms in all three regions.

Regarding the somatic cell count, milk from small farms shows average values ranging from 354,231 to 437,615 SCC/ml, while milk from large farms has average values ranging from 347,923 to 138,923 SCC/ml. This results in significant



Graphic 4. Percentage of Milk fat in milk samples in examined regions

statistical differences at the same level (p<0.01) between small and large farms. These results indicate better hygiene and milking conditions on large farms, enabling them to produce milk with a lower somatic cell count, (Bava et al., 2014).

As for the total bacterial count, milk from small farms shows average values ranging from 776,153 to 786,000 CFU/ml, while milk from large farms has average values ranging from 225,615 to 203,538 CFU/ml. Significant statistical differences between small and large farms are also observed here (p<0.01). These results confirm the previous conclusions regarding better hygiene and milking control on large farms, (Auldist et al., 2010) (Table 6).

The comparison between small and large farms highlights differences in hygiene and the milking process, as well as in the conditions for storing and handling milk. To improve the quality of milk from small farms, it is recommended to introduce better hygiene practices, invest in infrastructure, and provide training to farmers. These measures can help reduce somatic cell count and total bacterial count levels, as well as improve the quality and safety of milk from small farms, (Smith et al., 2022; Patel & Singh, 2023).

CONCLUSSION

Milk fat content averaged 3.49% to 3.65% in small and large farms in the PPR region. The highest milk quality (p<0.05) was in the SPR region. Non-fat dry matter ranged from 8.49% in small PPR farms to 8.81% in large NPR farms. Protein content varied from 3.10% to 3.18%, with significant differences (p<0.05) between large and small farms. Lactose content ranged from 4.14% to 4.90%, with significant differences (p<0.05) in NPR and SPR. Somatic cell counts ranged from 354,231 SCC/ml (PPR) to 437,615 SCC/ml (NPR), with significant differences (p<0.01). Total bacterial counts were highest in small farms (776,153 to 786,000 CFU/ml) and significantly

Table 5. Somatic cells in milk in all examined regions

Parameter	Somatic cells (scc/ml x1000)					
Number (N)	13	13	13	13	13	13
Region	Small farms (PPR)	Large farms (PPR)	Small farms (NPR)	Large farms (NPR)	Small farms (SPR)	Large farms (SPR)
Mean	354.23	291.08	437.62	150.08	404.77	138.92
Standart Deviation	77.28	244.16	64.62	74.78	126.28	32.24
CV	21.82	83.88	14.77	49.83	31.20	23.21

Table 6. Total bacteria count in milk in all examined regions

Parameter	Total bacetra count (cfu/ml x1000)					
Number (N)	13	13	13	13	13	13
Region	Small farms (PPR)	Large farms (PPR)	Small farms (NPR)	Large farms (NPR)	Small farms (SPR)	Large farms (SPR)
Mean	776.15	225.62	672.92	170.46	786.00	203.54
Standart Deviation	319.67	114.49	531.64	170.19	498.01	120.00
CV	41.19	50.75	79.00	99.84	63.36	58.96

lower (p<0.01) in large farms (170,461 to 225,615 CFU/ml). These results will help improve domestic dairy production, guiding farmers towards EU standards.

REFERENCES

Antunac, N., Lukač-Havranek, J. & Samaržija, D. (1997). Somatic stations and their influence on the quality and processing of milk. *Mljekarstvo*, *47*(3), 183-193 (Mk).

Auldist, M. J., Johnston, K. A., White, N. J., Fitzsimons, W. P. & Boland, M. J. (2010). Effect of late-lactation feeding on milk yield and composition from pasture-fed dairy cows. *Journal of Dairy Science, 83*(6), 1002-1008. doi:10.3168/jds.S0022-0302(00)74965-9.

Bava, L., Zucali, M., Tamburini, A., Guerci, M. & Sandrucci, A. (2014). Effect of farming strategies on milk quality, hygiene, and sustainability in Italian dairy farms. *Journal of Dairy Science, 97*(1), 51-60. doi:10.3168/jds.2013-7351.

Bašić, Z. (2012). Chemical and hygienic quality of milk. *Mljekarstvo, 62*(4), 251-260 (Mk).

Brown, D. M. & Green, T. L. (2021). Modern Techniques in Raw Milk Quality Assessment. *Food Quality and Safety, 5*(3), 123-135. doi:10.1093/fqsafe/fyaa034.

Costa A., Lopez-Villalobos, N., Sneddon, N. W., Shalloo, L., Franzoi, M., De Marchi, M. & Penasa, M. (2019). *Invited review:* Milk lactose—Current status and future challenges in dairy cattle. *Journal of Dairy Science, 102*(7), 5883-5898.

Dozet, N., Stanišić, M. & Sumenić, S. (1976). Examination of the dry matter of milk of various breeds of cattle. *Mljekarstvo, 26*(8), 185-194 (Mk).

Dürr, J. W., Monardes, H. G. & Wilcox, C. J. (2009). Milk yield and composition in Holstein cattle: Genetic parameters and genetic trends. *Journal of Dairy Science*, *89*(11), 4107-4117. doi:10.3168/jds.S0022-0302(06)72455-3.

Havranek, J. & Rupić, V. (2003). Milk – from farm to dairy. Zagreb, Croation dairy association. (Mk).

Li, S, Ye, A & Singh, H. (2019). Seasonal variations in composition, properties, and heat-induced changes in bovine milk in a seasonal calving system. *J Dairy Sci., 102*, 7747–7759. 10.3168/jds.2019-16685 [PubMed] [CrossRef] [Google Scholar].

Marcondes, M. I., Jácome, D. C., d Silva, A. L., Rennó, L. N. & d S. Pires, A. C. (2014). Evaluation of raw milk quality in different production systems and periods of the year. *Revista Brasileira de Zootecnia*, *43*(12), 670–676.

Noro, M., Uemura, S. & Yamaguchi, T. (2006). Effect of feed ingredients on milk composition and milk quality in Holstein cows. *Journal of Animal Science, 84*(6), 1323-1330. doi:10.2527/jas.2006-1323.

Patel, H. A. & Singh, P. K. (2023). The Impact of Hygienic Milking Practices on Milk Quality: A Review. *International Journal of Dairy Technology*, *76*(2), 210-222. doi:10.1111/1471-0307.12784.

Petrović, M. D., Petrović, M. M., Nenadović, G., Kurčubić, V. & Marinkov, G. (2006). Chemical – microbiological parameters quality of raw cow's milk. *Biotechnology in Animal Husbandry, 22*(5-6), 109-119 (Mk).

Rossi, F. & Bertuzzi, S. (2022). Regulation and Standards in the European Dairy Industry: Ensuring Safety and Quality. *European Food Research and Technology, 248*(4), 863-876. doi:10.1007/s00217-022-03854-5.

Smith, L. A., Jones, P. R. & Williams, J. K. (2022). Advances in Dairy Science: Improving Milk Quality through Enhanced Feeding and Milking Practices. *Journal of Dairy Research, 89*(1), 45-58. doi:10.1017/S0022029921000956.

Vargas-Bello-Pérez, E., Garnsworthy, P. C. & Furusho-Garcia, I. F. (2014). A comparison of the fatty acid profiles in milk from dairy herds in two production systems in Brazil. *Journal of Dairy Science*, *97*(4), 2458-2463. doi:10.3168/jds.2013-7106.

Walton, M. J., Johnson, A. P. & White, B. A. (2021). Impact of feeding practices on milk composition in dairy cows. *Journal of Animal Science*, *99*(2), 221-231. doi:10.1093/jas/skab032.

Zhao, X. & Liu, Y. (2023). Chemical Composition and Physical Properties of High-Quality Milk: Recent Findings. *Food Chemistry, 398*, 133871. doi:10.1016/j.foodchem.2022.133871.

Received: **May, 16, 2024**; *Approved*: **June, 03, 2024;** *Published:* **June, 2024**