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COMPARISON OF MILK PRODUCTION AND CHEMICAL COMPOSITION IN HOLSTEIN AND MONTBELIARDE BREEDS

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Abstract

The objective of this study is to compare the milk quality and production performance of Holstein and Montbeliarde cows raised under similar conditions. The analysis included 1,942 Holstein cows and 775 Montbeliarde cows. Significant differences were found in key parameters. Holsteins had a higher 24-hour milk yield (30.05 ± 0.10 kg) compared to Montbeliardes (27.22 ± 0.07 kg). However, Montbeliardes showed higher fat content (4.02 ± 0.03%) than Holsteins (3.66 ± 0.02%). The protein content was similar, with 3.61 ± 0.01% for Holsteins and 3.59 ± 0.02% for Montbeliardes. Somatic cell count was lower in Montbeliardes (867.99 ± 41.98 thousand/mL) compared to Holsteins (1849.96 ± 41.98 thousand/mL). Montbeliarde cows also displayed more consistent casein content (2.88 ± 0.02%) compared to Holsteins (2.96 ± 0.02%). These findings highlight the importance of selecting appropriate breeds and adopting specific management strategies to improve milk quality and yield. Better feeding, milking hygiene, and herd management can enhance economic efficiency and maintain a healthy dairy herd.

Key words*: Holstein, milk quality, milk production, Montbeliarde, protein.*

INTRODUCTION

Global milk production surpasses 820 million tons annually, with a yearly growth rate of 1% to 2%. Over 80% of this comes from dairy cows, while smaller portions are produced by buffaloes, small ruminants, and camels.

Milk is a key part of human diets worldwide. In Romania, it represents 30.9% of animal-based products and holds the largest share in this category. Its nutritional content, including proteins, amino acids, fatty acids, enzymes, and minerals, makes it crucial for health and physical development (Ben Fraj et al., 2024; Postolache et al., 2023). Despite its global significance, less than 10% of milk is traded internationally, mostly as butter, cheese, or milk powders (Acatincăi, 2004; Sandu, 2015).

Demand for dairy products has surged in Asia, Africa, and Latin America, while consumption remains steady in developed regions. Cattle farming plays a major socio-economic, biological, and ecological role by providing milk, meat, hides, and manure (Acatincăi, 2004).

In Europe, livestock production accounts for 65% to 75% of total agricultural output and follows strict animal welfare and environmental standards (Buckwell & Nadeu, 2018). Montbeliarde and Holstein breeds are notable for their distinct contributions to dairy farming.

Montbeliarde cattle, originally from mountainous areas of France, are known for their adaptability and dual-purpose use in milk and meat production. They perform well in harsh climates, such as the Vaslui region of Romania, which faces cold winters and dry summers. However, research on their genetic and productive traits under these conditions remains limited.

In contrast, Holsteins dominate industrial dairy systems, producing 96.43% of Europe's raw milk. They are highly productive, often exceeding 10,000 kg of milk per lactation, and play a key role in large-scale dairy operations (Sandu, 2015; ATF, 2017).

This study investigates the relationship between milk production and its chemical composition in Holstein and Montbeliarde breeds. By analyzing key parameters such as protein, fat, nitrogen fractions, and casein, it aims to provide insights into balancing milk yield and quality. The findings contribute to sustainable dairy farming practices and global efforts to improve production systems while maintaining nutritional quality.

MATERIALS AND METHODS

To meet the objectives of this study, two groups of dairy cows were analyzed under comparable conditions. The study included 1,942 Holstein cows and 775 Montbeliarde cows. Evaluated parameters were 24-hour milk yield (Kg_24), fat percentage (Fat), protein percentage (Protein), lactose percentage (Lactose), milk urea nitrogen (MUN), urea content (Urea), somatic cell count (SCC), and casein content (Casein).

Maintenance conditions covered shelter, feeding, watering, and milking systems to ensure uniformity across both groups. All cows were managed using standard practices suited to their breeds. Milk samples were collected and analyzed to assess key components of milk quality and yield.

The collected data were centralized and analyzed statistically. Calculated indicators included arithmetic mean ($\bar{X}$), standard deviation (s), and coefficient of variation (CV %). This approach enabled a reliable comparison of milk production and composition under similar conditions.

RESULTS AND DISCUSSIONS

The composition of milk in terms of fat and protein depends on factors such as species, breed, lactation stage, diet, and climate (Ben Fraj et al., 2023). Although these factors have been studied for many years, their effects are still not fully understood. Moreover, changes in dairy farming practices and feeding strategies over the decades have led to variations in milk composition. However, the increasing prevalence of Holstein cattle in Romania has reduced nitrogen levels, affecting protein content and nutritional value.

Milk is defined as the natural secretion of the mammary gland in farm animals, intended for consumption without alteration. It must be collected under hygienic conditions to ensure safety. Research indicates that milk produced in winter contains more dry matter, fat, and nitrogen than milk produced in summer.

Most carbohydrates in milk are present as lactose, although small amounts of free and combined carbohydrates are also found. However, available data are insufficient for detailed regional or seasonal comparisons.

The average milk production per breed is summarized in Table 1.

Table 1. The average value of milk production “Kg_24”

Breed	n	$\bar{X} \pm S_x$	S	CV %
Holstein	1942	24.54 ± 0.19	8.24	33.58
Montbeliarde	775	30.05 ± 0.10	8.73	29.07

$\bar{X}$ = arithmetic mean; $\pm s_{\bar{x}}$ = the error of the arithmetic mean; *s* = standard deviation, CV % = the coefficient of variability

Milk production comparison between Holstein and Montbeliarde cows showed significant differences in both yield and variability. Holstein cows produced an average of 24.54 ± 0.19 kg/day, with a standard deviation of 8.24 and a coefficient of variation (CV %) of 33.58%, indicating greater variability in daily yields. In contrast, Montbeliarde cows had a higher average yield of 30.05 ± 0.10 kg/day, a slightly higher standard deviation (8.73), but a lower CV % of 29.07%, reflecting more consistent yields. The lower coefficient of variation in Montbeliarde suggests better genetic stability and adaptability, especially under management systems focused on balancing productivity and robustness. The higher standard deviation in Montbeliarde, despite their lower CV %, can be explained by their greater absolute milk yield.

This finding contrasts with the conventional belief that Holsteins are superior in milk production, as most previous studies have emphasized Holsteins as the highest-yielding dairy breed. For instance, Dezetter et al. (2015) reported that Holsteins produce 951 to 1,588 kg more milk per lactation than Montbeliarde cows when accounting for environmental factors. However, our results align with studies conducted in low-input systems, such as Fiorelli (2018), where Montbeliarde cows demonstrated higher yields in grass-based systems without intensive feeding.

The lower variability in Montbeliarde milk production suggests that this breed performs well under various conditions and may be more suitable for extensive and mixed farming systems where production stability is prioritized over high yields. On the other hand, the higher variability observed in Holsteins likely reflects their sensitivity to changes in feeding strategies and environmental factors, which are linked to their greater metabolic demands for higher output. While Holsteins are traditionally favored for higher yields, our study indicates that Montbeliardes outperform them in terms of both yield consistency and overall productivity.

These findings highlight the importance of selecting breeds based on specific traits and production systems to optimize milk yield while ensuring stability and adaptability.

The comparison of milk protein content between Holstein and Montbeliarde cows is shown in Table 2, highlighting small differences in averages but significant implications for variability and production systems.

Table 2. The average value of protein

Breed	N	$\bar{X} \pm S_X$	S	CV %
Holstein	1942	3.61 ± 0.01	0.43	11.89
Montbeliarde	775	3.59 ± 0.02	0.40	11.31

$\bar{X}$ = arithmetic mean; $\pm s_{\bar{x}}$ = the error of the arithmetic men; *s* = standard deviation, CV % = the coefficient of variability

In this study, Holstein milk had an average protein content of 3.61 ± 0.01%, with a standard deviation of 0.43 and a coefficient of variation (CV %) of 11.89%. Montbeliarde milk recorded a similar average protein content of 3.59 ± 0.02%, but with a smaller standard deviation of 0.40 and a lower CV % of 11.31%. These results indicate that although the average protein content is similar between the two breeds, Montbeliarde milk is more consistent, which can be valuable for industrial uses requiring stable quality.

These findings are consistent with previous studies that highlighted the richness of Montbeliarde milk in terms of protein content. Benaicha & Sahi (2009), Meribai (2010), and Lerari & Idiri (2011) reported higher protein levels in Montbeliarde milk compared to Holstein. Earlier works by Froc et al. (1988), Macheboeuf et al. (1993), and Auldist et al. (2002), also noted a genetic predisposition of Montbeliarde and Normande breeds for producing protein-rich milk compared to Holsteins under similar environmental conditions.

This difference can be explained by the inverse relationship between milk yield and protein concentration. Holstein cows, with a higher average milk yield of 24.54 ± 0.19 kg/day, tend to produce milk with slightly lower protein content due to a dilution effect. In contrast, Montbeliarde cows, which have lower milk yields, produce milk with a more concentrated protein profile. This trend was also observed by Pissary & Dezendre (2006), as well as Agabriel et al. (1990), who highlighted the influence of genetic, physiological, and dietary factors on milk composition.

Although the protein content in both breeds differed slightly, the values remain within acceptable limits for cheese production and other applications. The lower CV % in Montbeliarde milk, reflecting higher consistency, provides an advantage for specific dairy products requiring uniform quality. Our results align with the ranges reported by Vierling (1999) and are slightly below those reported by Coulon et al. (1998) for Montbeliarde (34.1-34.5 g/l) and Fredot (2006), who found an average protein content of 34.4 g/l.

From a practical perspective, the differences in protein content highlight the importance of breed selection in improving milk quality. While Holstein cows are preferred for high-yield production, Montbeliarde cows have a genetic advantage in producing milk with more consistent protein content. This makes Montbeliarde milk particularly valuable for artisanal and specialized dairy products, where curd yield and quality depend on consistent protein levels.

Overall, Montbeliarde cows offer a slight advantage in protein consistency, making them suitable for dairy systems prioritizing quality over quantity. However, Holstein milk remains beneficial for large-scale production due to its higher yield. These findings underscore the need for careful breed selection based on production goals, balancing milk yield, protein concentration, and market demand for efficient dairy operations.

The casein content analysis between Holstein and Montbeliarde cows is summarized in Table 3, showing small differences in averages but notable differences in stability.

Table 3. The average values of casein

Breed	N	$\bar{X} \pm Sx$	S	CV %
Holstein	1942	2.96 ± 0.02	0.53	17.90
Montbeliarde	775	2.88 ± 0.02	0.40	10.37

$\bar{X}$ = arithmetic mean; $\pm s_{\bar{x}}$ = the error of the arithmetic mean; *s* = standard deviation, CV % = the coefficient of variability

Holstein milk had a slightly higher average casein content (2.96 ± 0.02%) compared to Montbeliarde milk (2.88 ± 0.02%). However, Montbeliarde milk showed better stability, with a lower coefficient of variation (CV % = 10.37) compared to Holstein milk (CV % = 17.90%). This greater uniformity in Montbeliarde milk makes it more suitable for industrial applications, such as cheese production, where consistent casein levels are essential.

This difference may be due to genetic or compositional factors affecting the variability in Holstein milk. Studies by Cerbulis & Farell (1975) noted that Holstein milk often contains high levels of non-protein nitrogen (NPN), which may reduce the casein-to-protein ratio when total nitrogen is measured instead of true protein. Le Doré et al. (1986) also found that Holstein cows have a slight disadvantage in casein-to-protein ratios, with differences of about 0.5 points compared to Montbeliarde cows, highlighting the compositional stability advantage of Montbeliarde milk.

Despite these differences, both breeds produce milk with sufficient casein levels to meet the needs of the dairy industry. The lower variability in Montbeliarde milk supports better curd yield and consistent texture, making it particularly valuable for high-added-value cheese production. In contrast, the higher variability in Holstein milk may pose challenges for achieving consistent quality in industrial processes requiring homogenization.

Overall, while Holstein milk has a slightly higher average casein content, the greater stability of Montbeliarde milk ensures better uniformity for dairy applications. These findings are consistent with previous studies by Le Doré et al. (1986) and Cerbulis & Farell (1975), which reported distinct compositional characteristics in these breeds and their industrial relevance.

This study examines the fat content in the milk of Holstein and Montbéliarde cows, highlighting significant differences between the two breeds. As shown in Table 4, Montbéliarde milk had a higher average fat content (4.02 ± 0.03%) compared to Holstein milk (3.66 ± 0.02%). However, this difference was accompanied by greater variability, as indicated by a higher coefficient of variation (CV % = 27.11) compared to Holstein milk (CV % = 23.89%). Additionally, the higher standard deviation in Montbéliarde milk (1.09) compared to Holstein milk (0.88) further supports this greater variability. In contrast, Holstein milk exhibited a more uniform fat content, which is beneficial for standardized industrial production.

Table 4. The average value of Fat

Breed	N	$\bar{X} \pm Sx$	S	CV%
Holstein	1942	3.66 ± 0.02	0.88	23.89
Montbeliarde	775	4.02 ± 0.03	1.09	27.11

$\bar{X}$ = arithmetic mean; $\pm s_{\bar{x}}$ = the error of the arithmetic mean; *s* = standard deviation, CV % = the coefficient of variability

These results are consistent with those of Martin et al. (2000) and Sebedio (2008), who found that Montbeliarde milk contains more fat, making it suitable for producing butter and cheese. This genetic predisposition in Montbeliardes is valuable for dairy systems focused on high added-value products.

Interestingly, these findings contradict those of Cauty & Perreau (2003), who suggested that Holstein milk had higher fat content. However, such differences may result from variations in feeding practices, environmental factors, or methodologies used in different studies. Moreover, the fat levels recorded in this study, particularly for Montbeliarde milk, were higher than the 34 g/l reported by Alais (2003) and the 34-42 g/l range suggested by Vierling (1999). This discrepancy could be attributed to differences in feeding methods, environmental conditions, or the timing of the study.

The high fat levels observed in this study may also be linked to nutritional factors. Labarre (1994) indicated that feeding cows silage maize, sorghum, green forages, or alfalfa, combined with dairy concentrate supplementation, increases milk fat content by enhancing fiber intake and appetite. Additionally, the study was conducted between late April and early May, a period of dietary transition known to influence milk composition.

Milk fat variability results from both intrinsic and extrinsic factors. Previous studies have identified genetics, lactation stage, and production levels as key intrinsic factors, while season, temperature, and feeding were highlighted as extrinsic factors. Croguennec et al. (2008) found that fat content decreases

during early lactation and increases in later stages. Since most cows in this study were in late lactation, this likely explains the higher fat levels observed.
The results also highlight the impact of genetic selection on milk composition. Breeding programs that focus on increasing milk yield, as noted by Pougheon & Goursaud (2007), can lower fat content. However, selection programs targeting fat yield help maintain higher and more consistent fat content. The findings suggest that Montbeliarde cows have benefited from such strategies, achieving a balance between milk yield and fat quality.
In conclusion, Montbeliarde cows had a higher fat content, making their milk more suitable for high-value dairy products, whereas Holstein milk, with its greater uniformity, is advantageous for standardized large-scale production. These findings emphasize the importance of balancing milk yield and quality, suggesting that management strategies should be tailored to production goals, whether focusing on higher quantity or better quality for specific markets.
The lactose content comparison between Holstein and Montbeliarde cows is summarized in Table 5, highlighting differences in both average concentrations and variability.

Table 5. The average value of lactose

Breed	N	$\bar{X} \pm Sx$	S	CV %
Holstein	1942	4.73 ± 0.01	0.38	8.00
Montbeliarde	775	4.83 ± 0.01	0.17	3.53

$\bar{X}$ = arithmetic mean; $\pm s_{\bar{x}}$ = the error of the arithmetic mean; *s* = standard deviation, CV % = the coefficient of variability

Montbeliarde milk shows a higher average lactose content (4.83 ± 0.01%) and greater consistency (CV % = 3.53%) compared to Holstein milk, which has a slightly lower lactose content (4.73 ± 0.01%) and higher variability (CV % = 8.00%). This suggests a genetic predisposition in Montbeliardes to produce milk with more stable sugar levels, making it suitable for applications requiring consistent milk components, such as cheese-making or fermented dairy products.
Holstein cows, known for their high milk yields, exhibit slightly lower and more variable lactose levels, likely due to the metabolic demands of intensive milk production. In contrast, Montbeliarde cows, often raised in traditional or dual-purpose systems, benefit from consistent feeding and management practices, contributing to their more stable lactose levels. These findings are consistent with prior studies (Coulon et al., 1998; Labarre, 1994), which highlight the influence of both breed and environmental factors on milk composition.
From a practical perspective, Holstein milk, with its higher yield, is ideal for large-scale production, though its slightly higher variability may require processing adjustments. In contrast, Montbeliarde milk, with its higher and more stable lactose content, is better suited for specialized products like yogurt and lactose-derived goods, where consistency is crucial. Overall, these insights emphasize the value of breed-specific strategies in optimizing milk quality and meeting diverse market demands.
The average non-protein nitrogen (SUN) levels in the milk of Holstein and Montbéliarde cows are presented in Table 6, showing slight but notable differences. Holstein milk had a higher average SUN concentration (9.14 ± 0.02 mg/dL) compared to Montbéliarde milk (8.87 ± 0.03 mg/dL). Despite this difference, both breeds exhibited a constant standard deviation of 0.8 mg/dL. However, Holstein milk showed slightly more stable levels, with a lower coefficient of variation (CV % = 8.78%) compared to Montbéliarde milk (CV % = 9.11%). These values align with earlier studies indicating that SUN levels generally range between 8 and 12 mg/dL (Fredot, 2006).

Table 6. The average values of non-protein nitrogen

Breed	N	$\bar{X} \pm Sx$	S	CV %
Holstein	1942	9.14 ± 0.02	0.8	8.78
Montbeliarde	775	8.87 ± 0.03	0.8	9.11

$\bar{X}$ = arithmetic mean; ±s = the error of the arithmetic mean; s = standard deviation, CV % = the coefficient of variability

The slightly lower SUN levels in Montbeliarde milk may reflect better nitrogen utilization, as Montbeliarde cows, known for lower milk yield, tend to excrete less non-protein nitrogen in their milk. These findings are consistent with those reported by Auldist et al. (2002). In contrast, the higher milk yield of Holstein cows may contribute to increased nitrogen excretion, as demonstrated by Pissary & Dezendre (2006). Feeding practices also play a crucial role. Labarre (1994) demonstrated that diets rich in silage maize and alfalfa improve nitrogen utilization in Montbeliarde cows. These findings emphasize the importance of breed-specific feeding strategies and management practices in optimizing nitrogen efficiency. Although both breeds showed SUN values within the expected range, the lower levels observed in Montbeliarde milk highlight an advantage in terms of nitrogen management and reduced environmental impact.

The urea concentration in Holstein and Montbeliarde milk is summarized in Table 7, showing significant differences in average levels and variability.

Table 7. The average values of urea

Breed	N	X̄ ± Sx	S	CV %
Holstein	1942	28.84 ± 0.18	7.99	27.70
Montbeliarde	775	27.22 ± 0.07	4.94	30,50

X̄ = arithmetic mean; $\pm s_{\bar{x}}$ = the error of the arithmetic mean; *s* = standard deviation, CV % = the coefficient of variability

Holstein milk had a higher average urea concentration (28.84 ± 0.18 mg/dl) compared to Montbeliarde milk (27.22 ± 0.07 mg/dl). The standard deviation for Holstein milk was 7.99 mg/dl, with a coefficient of variation (CV %) of 27.70%, indicating moderate variability. In contrast, Montbeliarde milk exhibited a lower standard deviation (4.94 mg/dl) but a higher CV % of 30.50%, suggesting relatively greater variability despite lower urea levels.

The higher urea concentration in Holstein milk may reflect the breed's high milk yield, which increases nitrogen excretion due to higher dietary protein requirements. Conversely, the lower urea levels in Montbeliarde milk suggest more efficient nitrogen metabolism, likely due to better synchronization between dietary protein and energy intake. Both breeds exhibited urea levels within the typical range of 25-35 mg/dl reported in the literature (Fredot, 2006; Agabriel et al., 1990). Additionally, urea variability, as indicated by the CV %, is consistent with its known sensitivity to dietary changes (Coulon, 2005).

From a practical perspective, monitoring urea levels is essential for optimizing feeding strategies and improving nitrogen efficiency. Holstein milk's higher urea levels may indicate excess dietary protein or insufficient energy supply, requiring adjustments to feeding practices. In contrast, Montbeliarde milk's lower urea concentration highlights its potential for more sustainable production systems. These findings reinforce the need for tailored feeding strategies that balance productivity with environmental sustainability.

The somatic cell count (SCC) in Holstein and Montbeliarde milk is summarized in Table 8, showing significant differences in variability and consistency.

Table 8. The average values of SCC

Breed	N	X̄ ± Sx	S	CV %
Holstein	1942	613,42 ± 41.98	1849.96	3.02
Montbeliarde	775	613,42 ± 31.17	867,99	141,5

X̄ = arithmetic mean; $\pm s_{\bar{x}}$ = the error of the arithmetic mean; *s* = standard deviation, CV % = the coefficient of variability

Holsteins exhibit a standard error (±Sx) of 41.98 and a standard deviation (S) of 1849.96, resulting in a low coefficient of variation (CV %) of 3.02%. This indicates that SCC levels in Holstein milk are relatively consistent within the population. In contrast, Montbeliarde milk shows a smaller standard error (±Sx) of 31.17 and a standard deviation (S) of 867.99, but a remarkably high CV % of 141.5%, suggesting substantial variability in SCC at the individual level. These findings imply that while Montbeliarde milk exhibits reduced variability in sample means, its individual SCC values are more influenced by external factors, whereas Holstein milk displays greater stability.

Somatic cells, mainly leukocytes (lymphocytes, macrophages, and polymorphonuclear cells), play an essential role in the natural defense mechanisms of milk, reflecting the immune system's response to intramammary infections. Elevated SCC levels are typically linked to subclinical mastitis and inflammation, which can affect milk quality by altering protein degradation and reducing soluble casein levels (Ng-Kwai-Hang et al., 1984).

Environmental and management factors are key contributors to SCC variability, as shown in previous studies (Quist et al., 2008; Gavan et al., 2009;). Holstein milk's lower SCC variability makes it more suitable for industrial dairy production, while Montbeliarde milk, despite its higher variability, remains ideal for traditional dairy products requiring richer composition. These findings highlight the importance of controlling SCC to improve milk quality and adapt production strategies to breed-specific needs.

CONCLUSIONS

This study highlights distinct differences in dairy performance and milk composition between Holstein and Montbéliarde cows, emphasizing the impact of breed-specific traits on milk yield, composition, and consistency. While Holstein cows demonstrated higher milk yield, Montbéliarde cows produced milk with more stable fat and protein content, making it well-suited for high-value dairy products. Variability in casein, urea, and somatic cell count further underscores the influence of genetic and management factors on milk quality.

These findings emphasize the importance of selecting breeds based on production objectives, whether prioritizing high-yield efficiency for industrial processing or compositional stability for specialized dairy products. Future research should focus on optimizing breeding programs and nutritional strategies to enhance milk quality while ensuring sustainable dairy production systems.

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