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Regional differences in milk production traits and mastitis prevalence in Holstein cows

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Abstract

The aim of this research was to analyse the variability of milk production traits and mastitis prevalence in Holstein cows across three breeding regions in Croatia: Central, Eastern, and Mediterranean. Data were derived from test-day records and included daily milk yield (DMY), fat and protein content, somatic cell count (SCC), and urea concentration. The differences due to the breeding region were observed in all analysed traits. The Eastern region exhibited the highest milk yield and fat production, which may be associated with more optimized nutritional and herd management practices. In contrast, the Mediterranean region recorded the lowest production parameters, likely reflecting the impact of environmental stressors, particularly elevated temperatures. The Central region showed intermediate production levels but the highest SCC values, indicating a greater risk of compromised udder health. Mastitis prevalence varied among regions, with the highest incidence of clinical mastitis recorded in the Central region. Similar regional patterns were observed for subclinical mastitis. These findings confirm the multifactorial influence of environmental conditions, management systems, and genetic background on milk production performance and udder health. In conclusion, the results highlight the importance of region-specific management strategies in dairy production systems. Identifying regional variability in milk traits and mastitis prevalence provides a basis for developing targeted interventions aimed at improving productivity, udder health, and overall animal welfare in Holstein populations.

Keywords: Holstein cows, milk production, mastitis prevalence, breeding region, somatic cell count

INTRODUCTION

Dairy cattle are susceptible to various health disorders that can adversely affect their milk production, well-being, and overall efficiency of dairy farms (Hogeveen et al., 2019). The most commonly reported disorders include mastitis, metabolic imbalances, lameness, digestive disturbances, reproductive dysfunctions, respiratory diseases, parasitic infections, and heat stress. Maintaining the health and productivity of dairy cattle requires the implementation of preventive measures, routine veterinary examinations, and appropriate treatments (Nir, 2003). Mastitis, an inflammatory disease of the mammary gland, is one of the most prevalent and economically significant health concerns in dairy farming (Seegers et al., 2003; Halasa et al., 2007; Benić et al., 2018; Hadrich et al., 2018; Maćešić et al., 2022; Chen et al., 2023). Therefore, mastitis represents a major challenge for the dairy industry, as it negatively impacts both individual animal performance and overall herd productivity (Halasa et al., 2007; Hadrich et al., 2018; Chen et al., 2023). The consequences of this disease encompass several key areas, including reduced milk yield, alterations in milk composition, economic losses, compromised milk quality, increased veterinary expenditures, reproductive inefficiencies, higher culling rates,

elevated somatic cell count (SCC), concerns regarding animal welfare, potential disease transmission within the herd, and long-term impairments to udder health (Halasa et al., 2007).

A decline in milk production is a direct consequence of mastitis, primarily due to the inflammatory response and structural damage to the mammary gland (Seegers et al., 2003). Additionally, infected cows often produce milk with compositional changes, including elevated SCC, increased concentrations of white blood cells, and imbalances in key milk constituents such as fat and protein (Schukken et al., 2003). The economic ramifications of mastitis are substantial, as financial losses stem from reduced milk output, veterinary interventions, discarded milk, and the need for culling chronically affected cows (Halasa et al., 2007; Hadrich et al., 2018). The costs associated with mastitis management are further exacerbated by veterinary treatments, including antibiotic therapy and supportive care. Reproductive performance may also be adversely affected, with mastitis contributing to prolonged intervals between estrous cycles, lower conception rates, and extended days open, largely due to the systemic inflammatory effects on fertility (Seegers et al., 2003). In cases of severe or recurrent mastitis, culling is often necessary to control disease transmission and mitigate economic losses. From an animal welfare perspective, mastitis induces pain and discomfort, reinforcing the necessity of effective management strategies and timely therapeutic interventions to reduce suffering. The contagious nature of certain mastitis-causing pathogens further underscores the importance of implementing biosecurity measures to prevent disease spread within the herd (Benić et al., 2018). Additionally, persistent or recurrent mastitis can have long-term repercussions on udder health, potentially leading to irreversible tissue damage and sustained reductions in milk production, even following treatment (Schukken et al., 2003).

Mastitis affects various breeds, with general characteristics remaining similar across breeds, although variations in pathogen prevalence may exist (Nóbrega and Langoni, 2011). Holstein cows, recognized for their high milk yield, may be more vulnerable to mastitis due to the increased physiological stress placed on their mammary glands. Furthermore, Holsteins are considered to be more susceptible to mastitis caused by environmental pathogens, such as Escherichia coli and environmental streptococci. According to Benić et al. (2018), bovine mastitis is predominantly of infectious origin, with approximately 150 microbial species identified as potential causative agents. Among them, Staphylococcus aureus is the most frequently isolated pathogen, posing a potential health risk to humans. The same authors also emphasize that the dairy cow's environment is heavily colonized by microbial communities, with pathogens typically entering the mammary gland through contaminated bedding or mud. Holstein cows affected by mastitis may exhibit clinical signs such as udder swelling, redness, and increased local temperature. Milk from infected quarters may display alterations in color and consistency. Additionally, due to their larger udders and longer teats compared to other dairy breeds, Holsteins are more prone to injuries and contamination during milking, increasing the risk of mastitis development.

The early detection of mastitis in dairy cattle is crucial for effective disease management and therapeutic intervention (Argaw, 2016). Various diagnostic techniques and technologies are available to identify mastitis at an early stage, thereby improving treatment outcomes (Narváez-Semanate et al., 2022). Some of the most widely used approaches for mastitis detection include clinical assessment, somatic cell count (SCC) evaluation, measurement of milk electrical conductivity, udder temperature monitoring, bacteriological culture, the California Mastitis Test, automated milk analyzers, machine milking parameters, rapid mastitis tests, teat-end condition monitoring, and automated health surveillance systems. Furthermore, SCC is a widely recognized marker of mastitis, given its strong correlation with inflammatory responses in the mammary gland (Schukken et al., 2003; Ivanov et al., 2016; Petzer et al., 2017). Blackburn (1966) reported that SCC levels increase progressively across successive lactations due to a higher presence of polymorphonuclear leukocytes (PMNs). However, fluctuations in SCC within a single lactation are associated with an increase in both PMNs and other somatic cells in milk. According to Smith et al. (2001), an SCC below 100,000 cells/ml is indicative of a healthy udder, whereas Mikó et al. (2016) suggested that normal milk typically contains SCC values ranging from 20,000 to 100,000 cells/ml. Elevated SCC levels are associated with milk production losses, leading to economic consequences for dairy farmers (Mikó et al., 2016; Hadrich et al., 2018).

The extent of milk yield reduction depends on SCC distribution at the individual cow level and across different parities within the herd (Chen et al., 2023). Pfützner and Ózsvári (2016) reported that cows with SCC values between 50,000 and 100,000 cells/ml experienced milk yield reductions exceeding 8%, while

those with SCC levels ranging from 100,000 to 250,000 cells/ml exhibited production losses exceeding 15%, reaching up to 18% in some cases. Gantner et al. (2011, 2017) investigated the relationship between heat stress and SCC in Holstein cows, highlighting fluctuations in SCC based on the temperature-humidity index, daily milk yield, breed, and parity. Furthermore, the effect of lactation stage, parity, season, and geographic region on SCC levels has been documented in multiple studies (Blackburn, 1966; Seegers et al., 2003; Nóbrega and Langoni, 2011; Yang et al., 2013; Tomazi et al., 2018; Weber et al., 2020; Stocco et al., 2023; Chen et al., 2023).

Considering the importance of mastitis prevalence analysis on dairy farms, this research aimed to determine the variability in the daily milk traits (milk quantity and quality) and the prevalence of subclinical and clinical mastitis in Holsteins due to the region of breeding using the test-day records.

MATERIAL AND METHODS

The statistical analysis in this research was based on test-day records of Holstein cows, collected over a 10-year period from January 2013 to December 2022 as part of routine milk recording. The milk recording procedure followed the standards established by the International Committee for Animal Recording (ICAR, 2017) for alternative milk recording methods (AT4/BT4). This approach involved measuring milk yield and obtaining milk samples from each cow during either the morning or evening milking at four-week intervals. Furthermore, data collection was conducted by trained officers from the Croatian Agency for Agriculture and Food (HAPIH) for the AT4 method, while farm employees trained in milk recording performed the BT4 method. Following sample collection, milk was transported to the accredited Central Laboratory for Milk Quality Control (SLKM) of HAPIH for analysis, ensuring compliance with ICAR (2017) protocols.

The chemical composition of milk, including fat, protein, lactose, total solids, solids-not-fat, urea, casein, free fatty acids, pH, ketone bodies, and freezing point, was analyzed using infrared spectrophotometry on MilkoScan analyzers. Additionally, somatic cell counts were determined using Fossomatic analyzers based on the fluoro-opto-electronic method.

Prior to the application of logical data control procedures, the dataset obtained from HAPIH comprised over 4 million test-day records. As part of the data validation process, records that did not conform to the standards established by ICAR (2017) were excluded. Additionally, records with incomplete or inaccurate information related to breed, farm identification, breeding region, lactation stage, parity, age at first calving, calving date, and milk recording date were removed to ensure data accuracy and consistency. Following these quality control measures, the final dataset included 2,509,222 test-day records of Holstein cows. Furthermore, regarding the location of farm records were grouped into three breeding regions: Central, Eastern, and Mediterranean.

Daily somatic cell count (SCC) was used as a key indicator for detecting subclinical and clinical mastitis in dairy cows. Cows were categorized into mastitis classes based on SCC thresholds: cows with SCC below 200,000 cells/ml were classified as healthy, those with SCC between 200,000 and 400,000 cells/ml were considered to have subclinical mastitis, while SCC exceeding 400,000 cells/ml indicated clinical mastitis.

The prevalence of subclinical and clinical mastitis was determined as the proportion of cows within each mastitis category relative to the total number of animals, both overall and per breeding region.

Variability in milk production traits and SCC was assessed using descriptive statistics, including coefficients of variation, while frequency distributions were analyzed to evaluate the occurrence of mastitis categories across breeding regions. All statistical analyses were performed using SAS software (SAS Institute Inc., Cary, NC, USA), version 9.4.

RESULTS AND DISCUSSION

The results of the analysis of the variability in milk production traits of Holstein cows across different breeding regions are presented in the following table 1.

Table 1. Parameters of variability of daily milk yield traits of Holstein cows depending on the breeding region (Central, Eastern and Mediterranean Croatia)

Region	DMY kg				DFC %				DFY			
	N	Mean	SD	CV	N	Mean	SD	CV	N	Mean	SD	CV
CE	953964	23.3	9.32	39.917	953964	4.1	0.94	22.774	953964	1.0	0.43	44.854
ES	1440575	27.3	10.43	38.162	1440575	4.2	0.99	23.724	1440575	1.1	0.50	44.098
ME	114683	24.1	9.46	39.284	114683	3.9	0.90	23.131	114683	0.9	0.40	43.489
Total	2509222	25.7	10.17	39.605	2509222	4.1	0.97	23.379	2509222	1.1	0.47	45.193
Region	DPC %				DPY				DLC %			
	N	Mean	SD	CV	N	Mean	SD	CV	N	Mean	SD	CV
CE	953964	3.4	0.44	12.995	953964	0.8	0.30	38.747	953964	4.5	0.22	4.899
ES	1440575	3.4	0.42	12.134	1440575	0.9	0.33	35.807	1440575	4.5	0.23	5.060
ME	114683	3.4	0.43	12.830	114683	0.8	0.30	37.593	114683	4.5	0.22	4.982
Total	2509222	3.4	0.43	12.506	2509222	0.9	0.33	37.757	2509222	4.5	0.22	4.999
Region	SSC*10^3				SSC log				Urea mg/dL			
	N	Mean	SD	CV	N	Mean	SD	CV	N	Mean	SD	CV
CE	953619	496.7	1102.60	221.981	953619	7.3	2.08	28.431	953964	20.1	9.71	48.298
ES	1440364	416.6	1018.35	244.427	1440364	7.0	2.06	29.517	1440575	23.5	8.36	35.653
ME	114677	397.1	935.09	235.473	114677	6.9	2.10	30.362	114683	23.0	9.64	41.905
Total	2508660	446.2	1048.38	234.970	2508660	7.1	2.08	29.225	2509222	22.2	9.10	41.071

*DMY – daily milk yield (kg); DFC – daily fat content (%); DFY – daily fat yield (kg); DPC – daily protein content (%); daily protein yield (kg); DLC – daily lactose content (%); SSC*103 – somatic cell count; SSC log – log value of SSC; Urea – urea content in milk (mg/dL); CE – Central; ES – Eastern; ME – Mediterranean

Regarding daily milk yield (DMY), the highest average value was observed in the Eastern region (ES) with 27.3 kg, followed by the Mediterranean region (ME) at 24.1 kg and the Central region (CE) at 23.3 kg. The coefficient of variation (CV) for DMY was relatively similar across all regions, ranging from 38.162% in the Eastern region to 39.917% in the Central region, indicating moderate variability in milk yield within each region. For daily fat content (DFC), cows from the Eastern region (ES) had the highest average fat percentage (4.2%), followed closely by the Central region (CE) at 4.1%, while cows in the Mediterranean region (ME) had the lowest fat content (3.9%). The CV values for fat content ranged from 22.774% in the Central region to 23.724% in the Eastern region, demonstrating moderate variability in fat content across regions. In terms of daily fat yield (DFY), the Eastern region (ES) also exhibited the highest average fat yield at 1.1 kg, while the Central region (CE) and Mediterranean region (ME) had lower values of 1.0 kg and 0.9 kg, respectively. The CV for DFY ranged from 43.489% in the Mediterranean region to 45.193% in the overall dataset, indicating a considerable amount of variation in fat yield. For the percentage of protein (DPC), the averages were similar across regions, with values of 3.4% in all three regions (CE, ES, ME). The CV for DPC ranged from 12.134% in the Eastern region to 12.995% in the Central region, indicating relatively low variability in dry matter content among cows in each region. The average daily protein yield (DPY) was highest in the Eastern region (ES) at 0.9 kg, followed by the Central (CE) and Mediterranean (ME) regions, both with 0.8 kg. The CV values for DPY ranged from 35.807% in the Eastern region to 38.747% in the Central region, indicating considerable variability in protein yield within each region. For daily lactose (DLC), cows in all regions showed similar values, with averages of 4.5%. The CV for DLC was low, ranging from 4.899% in the Central region to 5.060% in the Eastern region, suggesting minimal variability in daily lactose content across regions.

The somatic cell count (SSC) was highest in the Central region (CE), with an average of 496.7 × 10^3 cells, followed by the Eastern (ES) and Mediterranean (ME) regions at 416.6 × 10^3 cells and 397.1 × 10^3 cells, respectively. The CV for SSC ranged from 221.981% in the Central region to 244.427% in the

Eastern region, indicating significant variability in somatic cell count within each region. The log-transformed SSC (SSC log) was relatively consistent across regions, with the Central region (CE) having an average of 7.3, the Eastern region (ES) 7.0, and the Mediterranean region (ME) 6.9. The CV values for SSC log were comparable, ranging from 28.431% in the Central region to 30.362% in the Mediterranean region. Regarding urea content, cows from the Eastern region (ES) had the highest average urea level at 23.5 mg/dL, followed by the Mediterranean region (ME) at 23.0 mg/dL and the Central region (CE) at 20.1 mg/dL. The CV for urea content was highest in the Central region (48.298%), followed by the Mediterranean region (41.905%) and the Eastern region (35.653%).

The obtained results indicate clear regional differences in milk production parameters among Holstein cows, highlighting the influence of environmental, management, and feeding factors. The Eastern region generally exhibited the highest values for milk yield (DMY), fat content, and fat yield (DFY), likely reflecting more efficient milk production due to superior management practices, optimized feeding strategies, and potentially favorable climatic conditions (Gantner et al., 2011; Gantner et al., 2017). In contrast, the Mediterranean region recorded the lowest values, which can be attributed to challenging environmental conditions, particularly elevated temperatures, negatively affecting cow performance and milk quality (Gantner et al., 2011; Yang et al., 2013; Gantner et al., 2017). The Central region showed intermediate results across most parameters, although it presented the highest somatic cell count (SCC), indicating potential udder health concerns such as mastitis (Schukken et al., 2003; Cvetnić et al., 2016). Urea levels were highest in the Eastern region, suggesting higher protein intake or differences in nitrogen metabolism. The coefficient of variability for many traits ranged from moderate to high, demonstrating notable differences in milk production characteristics among individual cows within each region. Overall, these findings underscore the impact of regional factors on milk production and emphasize the need for tailored management strategies aimed at improving milk yield, enhancing milk quality, and maintaining udder health under differing environmental and management conditions (Antanaitis et al., 2021).

The results presented in Table 2 show the prevalence of mastitis in Holstein cows across three different breeding regions in Croatia: Central, Eastern, and Mediterranean.

Table 2. Mastitis prevalence in Holstein cows depending on the breeding region (Central, Eastern and Mediterranean Croatia)

Region		Animal's health status			Total
		Clinical	Normal	Subclinical	
Central	No	240930	562413	150621	953964
	%	25.26	58.96	15.79	100.00
Eastern	No	290634	954010	195931	1440575
	%	20.17	66.22	13.60	100.00
Mediterranean	No	23651	75848	15184	114683
	%	20.62	66.14	13.24	100.00

In the Central region, the prevalence of clinical mastitis was 25.26%, which represents the highest proportion of mastitis cases among the three regions. The normal (healthy) cows in this region accounted for 58.96%, while subclinical mastitis affected 15.79% of the cows. This suggests a relatively higher prevalence of clinical mastitis in the Central region compared to the other regions, which may be influenced by regional management practices, environmental conditions, or other factors that affect udder health. The Eastern region showed a lower prevalence of clinical mastitis at 20.17%, and a higher proportion of cows were classified as healthy, with 66.22% of cows in the normal group. Subclinical mastitis was present in 13.6% of the cows, which is similar to the Central region. The lower prevalence of clinical mastitis in the Eastern region may reflect better udder health management or more favorable environmental conditions for cow health. In the Mediterranean region, the prevalence of clinical mastitis was the lowest among the three regions, at 20.62%, and the proportion of healthy cows was also lower compared to the other two regions, at 66.14%. Subclinical mastitis affected 13.24% of the cows, which is slightly lower than in the Central and Eastern regions. The lower prevalence of clinical mastitis in the Mediterranean region may be linked to different environmental challenges, such as higher temperatures and humidity, which could potentially reduce the overall prevalence of clinical mastitis or affect the way it is diagnosed and managed. Finally, the Central region had the highest prevalence of clinical mastitis,

while the Eastern region had a higher proportion of healthy cows, and the Mediterranean region had the lowest prevalence of clinical mastitis. These regional differences suggest that environmental, management, and possibly genetic factors play a role in the prevalence and management of mastitis. It highlights the importance of region-specific strategies for mastitis control, including improving udder health management, optimizing cow comfort, and addressing any regional environmental challenges that may affect milk production and quality.

The results in Table 3 present the variability of daily milk yield traits of Holstein cows in relation to their health status, including healthy, subclinical mastitis, and clinical mastitis classes.

Table 3. Parameters of variability of daily milk yield traits of Holstein cows depending on the health status (health, subclinical or clinical mastitis)

Mastitis class	DMY kg				DFC %				DFY			
	N	Mean	SD	CV	N	Mean	SD	CV	N	Mean	SD	CV
Clinical	555215	23.6	10.09	42.69	555215	4.2	0.99	23.55	555215	1.0	0.47	48.26
Normal	1592271	26.8	10.06	37.50	1592271	4.1	0.96	23.42	1592271	1.1	0.47	43.51
Subclinical	361736	23.8	10.00	42.10	361736	4.2	0.96	22.76	361736	1.0	0.46	46.73
Total	2509222	25.7	10.17	39.61	2509222	4.1	0.97	23.38	2509222	1.1	0.47	45.19
Mastitis class	DPC %				DPY				DLC %			
	N	Mean	SD	CV	N	Mean	SD	CV	N	Mean	SD	CV
Clinical	555215	3.5	0.44	12.72	555215	0.8	0.33	40.75	555215	4.4	0.26	5.90
Normal	1592271	3.4	0.42	12.30	1592271	0.9	0.32	35.87	1592271	4.5	0.19	4.215
Subclinical	361736	3.5	0.44	12.60	361736	0.8	0.33	40.09	361736	4.4	0.22	4.99
Total	2509222	3.4	0.43	12.51	2509222	0.9	0.33	37.76	2509222	4.5	0.22	4.99
Mastitis class	SSC $*10^3$				SSC log				Urea			
	N	Mean	SD	CV	N	Mean	SD	CV	N	Mean	SD	CV
Clinical	555215	1618.5	1780.17	109.99	555215	10.1	1.14	11.31	555215	21.3	9.49	44.57
Normal	1591709	74.6	50.74	67.99	1591709	5.8	1.14	19.54	1592271	22.6	8.91	39.43
Subclinical	361736	281.7	56.86	20.18	361736	8.1	0.29	3.56	361736	21.6	9.20	42.64
Total	2508660	446.2	1048.38	234.97	2508660	7.1	2.08	29.23	2509222	22.2	9.10	41.07

DMY – daily milk yield (kg); DFC – daily fat content (%); DFY – daily fat yield (kg); DPC – daily protein content (%); daily protein yield (kg); DLC – daily lactose content (%); SSC$*10^3$ – somatic cell count; SSC log – log value of SSC; Urea – urea content in milk (mg/dL)

Cows with clinical mastitis had a slightly lower mean daily milk yield (DMY) of 23.6 kg compared to the healthy group, which had a mean DMY of 26.8 kg. The subclinical group showed a mean DMY of 23.8 kg, which is close to the clinical group but still lower than the normal group. Despite this, the coefficients of variation (CV) for DMY were similar across all mastitis classes, ranging from 37.5% in the healthy group to 42.7% in the clinical group, suggesting considerable variation in milk yield within each health status category.

Furthermore, in terms of daily fat content (DFC %), the clinical mastitis group had a slightly higher mean value (4.2%) compared to the healthy group (4.1%) and the subclinical group (4.2%), but the variability (SD) was similar across groups. The CV for DFC % was highest in the clinical group (23.6%), indicating more variation in fat content within the clinical mastitis group compared to the other two groups. Daily fat yield (DFY) was slightly higher in the healthy cows (1.1 kg) compared to both the clinical (1.0 kg) and subclinical groups (1.0 kg). The variability in DFY, was similar across all groups, indicating that the difference in daily fat yield between the groups may not be substantial, although there is still variability within each group. In terms of daily protein content (DPC), cows with clinical and subclinical mastitis showed similar values, with a mean of 3.5%, while normal cows had slightly lower value at 3.4%. Regarding daily protein yield (DPY), clinical and subclinical cows had a mean of 0.8 kg, with high

variability (CV of 40.75% and 40.09%, respectively), while normal cows had a higher mean of 0.9 kg and lower variability (CV of 35.87%). Daily lactose content (DLC%) was relatively consistent across all groups, with clinical and subclinical cows having a mean of 4.4% and normal cows 4.5%. The low variability in lactose content (CV around 5%) across all groups suggests that mastitis, even in subclinical cases, does not significantly alter lactose production (Antanaitis et al., 2021). For somatic cell count (SSC *103), the clinical mastitis group had the highest mean (1618.5 × 103), which is expected given the direct correlation between high SCC and mastitis (Petzer et al., 2017). The healthy cows had a much lower mean SCC (74.6 × 103), while the subclinical mastitis group had an intermediate mean (281.7 × 103). The CV for SCC was also highest in the clinical group (109.99), indicating more variability in SCC within this group compared to the other two. Urea levels were relatively similar across the groups, with the healthy cows having a slightly higher mean (22.6 mg/dL) compared to the clinical (21.3 mg/dL) and subclinical (21.6 mg/dL) groups. The CV for urea levels was relatively consistent across all groups, suggesting that urea levels are not heavily influenced by mastitis severity. The differences in analysed traits emphasize the impact of mastitis, particularly clinical mastitis, on milk production. The higher SCC and lower milk yield in cows with clinical mastitis were expected and suggest a direct negative effect on udder health and milk production. However, cows with subclinical mastitis did not show a significant reduction in milk yield or fat content, but the increased SCC still indicates an ongoing subclinical infection that could affect herd performance in the long term.

CONCLUSION

The obtained results indicate notable regional variations in milk production traits and the prevalence of mastitis in Holstein cows. The Eastern region demonstrated the highest levels of milk yield, fat content, and fat yield, suggesting a more efficient approach to milk production compared to the Central and Mediterranean regions. Moreover, the Central region showed elevated somatic cell counts (SCC), which may signal potential udder health issues. The prevalence of both clinical and subclinical mastitis was notably highest in the Central region. These results emphasize the significance of regional factors in the variability of milk yield, quality, and udder health. Consequently, sustainable management strategies are necessary to enhance milk production and quality while effectively addressing mastitis and mitigating its impact on dairy farms. Finally, research results emphasised the importance of considering regional differences to optimize the health and production of dairy cattle.

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