

SEASONAL DETERMINANTS OF MILK COMPOSITION IN DAIRY COWS UNDER MODERATE CLIMATIC CONDITIONS

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Introduction. Climatic variability is a key factor influencing the efficiency of dairy production systems under current global climate change. Increasing air temperature and fluctuations in environmental conditions directly affect productivity, milk composition, and physiological responses of dairy cows [1,2]. Heat stress, even under moderate conditions, alters thermoregulation, metabolism, and immune function, which may lead to changes in production parameters [1].

Milk yield and milk composition respond differently to environmental factors. While productivity often remains relatively stable due to adaptive mechanisms, fat and protein contents are more sensitive to thermal load, which has important economic implications [3,5]. In continental climates, seasonal effects are complex and may include delayed responses to summer heat exposure, particularly in Brown Swiss cows [3].

Seasonality represents an integrated expression of environmental conditions, combining climatic and management influences. However, it is not always an independent causal factor but rather reflects underlying environmental and physiological processes. Therefore, integrated analysis of climatic, productive, and clinical indicators is required for accurate interpretation of seasonal dynamics [2].

Objective. To evaluate the effect of seasonality on milk yield and milk composition in dairy cows and to determine the contribution of climatic and clinical predictors using a multifactorial modelling approach.

Materials and Methods. The study was conducted under commercial dairy farm conditions using herd-level data obtained throughout 2025. The analysis included Brown Swiss dairy cows maintained under a year-round free-stall housing system .

Productive indicators included milk yield (kg), fat content (%), and protein content (%). Clinical parameters comprised somatic cell count, mastitis incidence, and lameness prevalence. Environmental data (air temperature and relative humidity) were obtained from a meteorological station and used as indicators of thermal load [1,2].

The analytical framework was based on an integrated approach combining climatic, productive, and clinical indicators at the herd level [2]. Seasonal variability was analysed in relation to changes in milk composition, which is known to be sensitive to environmental conditions [3,5].

Statistical analysis was performed using Statistica 12.0. Seasonal differences were evaluated using one-way ANOVA, and relationships between variables were assessed using Pearson correlation coefficients. Generalized linear models (GLM) were applied to quantify the independent effects of climatic and clinical predictors. Effect size was evaluated using partial eta squared (η^2), and statistical significance was set at $p < 0.05$.

Results. Environmental conditions demonstrated clear seasonal variation, with low temperatures in winter and peak values in summer, while relative humidity followed an opposite trend.

Milk yield remained relatively stable across seasons and even increased during summer (up to 37.1 kg), indicating the presence of adaptive or management-related compensatory mechanisms. In contrast, milk composition showed pronounced seasonal variation. Fat and protein contents significantly decreased in summer (to 3.59% and 3.19%, respectively; $p < 0.001$), confirming their high sensitivity to thermal load.

Somatic cell count increased under elevated temperatures, suggesting activation of physiological or subclinical responses, whereas mastitis and lameness remained relatively stable, indicating effective herd management.

Correlation analysis revealed substantial seasonal restructuring of relationships between variables. The strongest associations were observed in autumn, where air temperature showed strong negative correlations with fat ($r = -0.79$; $p < 0.001$) and protein ($r = -0.77$; $p < 0.001$), indicating a delayed effect of summer heat exposure [3].

Generalized linear modelling confirmed that season had a strong effect on productivity traits ($\eta^2 = 49.18\%$ for milk yield, 69.85% for fat, and 56.77% for protein). However, after inclusion of climatic and clinical predictors, its contribution decreased substantially (to 23.60% , 26.09% , and 9.36% , respectively), indicating that seasonality primarily reflects underlying environmental and physiological factors.

Air temperature was identified as the main determinant of milk composition, reducing fat ($\eta^2 = 21.33\%$) and protein content ($\eta^2 = 17.31\%$), whereas somatic cell count explained variability in milk yield ($\eta^2 = 8.74\%$).

Conclusions. Seasonality significantly influences milk production traits; however, this effect is largely indirect and mediated by climatic and clinical factors. Milk yield demonstrated relative stability under moderate thermal conditions, whereas milk composition was highly sensitive to air temperature. The reduction in fat and protein content under elevated temperatures represents a key response to environmental load. Multifactorial modelling confirmed that climatic variables, particularly air temperature, are the primary drivers of these changes, while season acts as an integrated indicator of environmental conditions. These findings highlight the importance of considering both direct climatic effects and their seasonal structure when evaluating dairy productivity.

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