

SEASONAL THERMAL LOAD AND IMMUNE ADAPTATION IN DAIRY COWS: EVIDENCE FROM LEUKOCYTE INDICES

Chabanenko D.V., Mylostyvyi R.V.

e-mail: 11590948@student.dsau.dp.ua

Dnipro State Agrarian and Economic University, Dnipro, Ukraine

Introduction. Seasonal climatic variability in continental regions exposes dairy cows to alternating periods of heat and cold stress within a single production cycle. Heat stress is widely recognised as a major limiting factor in dairy production systems due to its negative effects on productivity, welfare, and physiological status of animals [1]. However, cold stress also represents an important environmental challenge in continental climates and may induce specific adaptive responses that differ from those observed under heat load [2].

Both heat and cold stress require activation of complex physiological and immunological mechanisms. Nevertheless, the direction and intensity of these responses are not identical, which suggests the formation of distinct patterns of immune adaptation. Previous studies have demonstrated that thermal stress can significantly affect leukocyte dynamics and immune reactivity in dairy cows [3].

Traditional assessment of immune status based on individual leukocyte counts may be insufficient under moderate stress conditions, as these parameters often remain within physiological ranges. In contrast, integral leukocyte indices (ILIs), which reflect relationships between leukocyte populations, provide a more sensitive and integrative evaluation of immune balance. Their applicability in veterinary research and clinical practice has been demonstrated in various models [4].

Despite this, comparative evaluation of immune responses to both heat and cold stress under natural production conditions remains limited. Therefore, there is a need to clarify whether these stressors induce similar quantitative changes or fundamentally different immune phenotypes.

Objective. To compare immune response patterns in dairy cows under moderate heat and cold stress using integral leukocyte indices as sensitive indicators of immune adaptation.

Materials and Methods. The study was conducted on Brown Swiss dairy cows ($n = 36$) maintained under identical housing and feeding conditions typical for intensive dairy production systems [5]. Animals were divided into three groups ($n = 12$ each): heat stress (HS), cold stress (CS), and thermoneutral control (CON), according to natural seasonal conditions.

Environmental exposure was characterised using the temperature–humidity index (THI), which is widely applied for assessing heat load in dairy cattle [1], as well as wind chill temperature (WCT) for cold stress evaluation. Heat stress conditions corresponded to moderate thermal load (maximum THI 77.4), whereas cold stress was defined by low THI values (minimum 12.7) and WCT reaching -15.1 °C.

Blood samples were collected prior to feeding. Total and differential leukocyte counts were determined using standard haematological methods. Based on these data, integral leukocyte indices were calculated, including nuclear shift index (NSI), leukocyte index of intoxication (LII), neutrophil-to-lymphocyte ratio (NLR), neutrophil-to-monocyte ratio (NMR), lymphocyte-to-monocyte ratio (LMR), and index of immune reactivity (IIR), following previously described approaches adapted for cattle [3].

Statistical analysis was performed using non-parametric methods. Differences between groups were assessed using Kruskal–Wallis and Mann–Whitney tests. Statistical significance was set at $p < 0.05$.

Results. Distinct patterns of immune response were observed under heat and cold stress conditions.

Under heat stress, a pronounced increase in the monocytic component of peripheral blood was detected. Monocyte levels increased nearly threefold compared with the control group ($p < 0.001$).

This was accompanied by a decrease in NMR and LMR, indicating a redistribution of leukocyte balance toward the monocytic lineage. In addition, the index of immune reactivity (IIR) decreased more than twofold ($p < 0.001$), suggesting reduced immune responsiveness despite the absence of leukopenia. Similar patterns of immune modulation under heat stress have been described previously [3].

In contrast, cold stress induced a different response pattern characterised by leukopenia. Total leukocyte count decreased by approximately 27% ($p < 0.01$). At the same time, the leukocyte index of intoxication (LII) increased, indicating enhanced stress-related or inflammatory processes. Changes in NMR, LMR, and IIR further confirmed a shift in immune balance toward reduced adaptive capacity.

Direct comparison between HS and CS demonstrated that, although both stressors affected leukocyte distribution, the resulting immune phenotypes were fundamentally different. Heat stress was associated with monocytic restructuring without reduction in total leukocyte count, whereas cold stress resulted in leukopenia combined with signs of immunosuppression.

Importantly, several individual leukocyte parameters remained within physiological limits, whereas integral indices clearly differentiated between stress conditions, confirming their higher diagnostic sensitivity.

Conclusions. Moderate heat and cold stress induce distinct patterns of immune adaptation in dairy cows. Heat stress is associated with monocytic predominance and reduced immune reactivity without leukopenia, indicating functional modulation of immune balance. In contrast, cold stress leads to leukopenia, increased indices of intoxication, and a more pronounced immunosuppressive profile. Integral leukocyte indices proved to be more sensitive than individual leukocyte parameters and allowed clear differentiation between stress conditions. These findings support the use of ILIs as practical tools for monitoring immune status under natural seasonal conditions.

References

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