



## The effect of prolonged heat stress on haematological parameters of Holstein cows

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**Abstract.** Prolonged heat stress poses a significant challenge to the productivity and health of Holstein cows due to their heightened sensitivity to high temperatures and intensive metabolism. The purpose of this study was to investigate changes in haematological and immunobiological parameters in Holstein cows under prolonged heat stress conditions. The study included 18 cows in their second and third lactations, which were divided into two groups: one exposed to hyperthermia during the summer (August) (HYP, n = 8), and the other maintained under thermally comfortable conditions in the autumn (October), serving as the control group (CON, n = 10). Blood analysis was performed using methods commonly accepted in clinical veterinary practice. The results revealed significant reductions in red blood cell count (by 14.5%), haemoglobin level (by 11%), and haematocrit (by 8.4%) in HYP cows compared to CON ( $P < 0.05$ ), indicating disruptions in erythropoiesis or reduced erythrocyte lifespan. Concurrently, an increase in mean corpuscular volume (by 8.9%) and platelet count (by 53%), alongside a decrease in mean platelet volume (by 20%), suggested adaptive metabolic and coagulation responses of the organism. A 48% decrease in serum lysozyme activity and a 36% increase in circulating immune complex levels indicated suppression of innate immunity and activation of compensatory immune defence mechanisms. The practical significance of the study lies in identifying potential biological markers for monitoring and managing heat stress, which could improve the health, productivity, and welfare of dairy cows

**Keywords:** dairy cattle; hyperthermia; blood parameters; erythropoiesis; innate resistance

### Introduction

Heat stress (HS) represents a significant challenge to livestock production globally, particularly for high-yielding dairy cows, which are highly sensitive to elevated temperatures

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and humidity. HS disrupts physiological homeostasis, leading to reduced milk production, impaired immune responses, and compromised overall welfare. For instance, prolonged exposure to elevated temperature-humidity index (THI) levels has been shown to reduce milk production by 30-40%, particularly in regions where summer temperatures frequently exceed 40°C (Zeng *et al.*, 2023). This decline is primarily attributed to metabolic alterations, including oxidative stress and systemic inflammation, which result from increased production of reactive oxygen species (ROS) and subsequent cellular damage (Sejian *et al.*, 2022).

A.M. Ferreira *et al.* (2023) reported that chronic heat stress induces profound alterations in the innate immune response, leading to dysregulation of acute-phase proteins such as serum amyloid A, transferrin, and hepcidin. These changes reflect systemic inflammatory processes triggered by prolonged exposure to high ambient temperatures. The disruption of homeostasis under thermal stress conditions is closely associated with metabolic shifts, affecting protein synthesis and degradation pathways, ultimately influencing immune competence and overall physiological stability. This metabolic adaptation, while aimed at preserving cellular function, often compromises immune efficiency and antioxidant defence mechanisms, increasing susceptibility to inflammatory and oxidative damage (Mylostyva *et al.*, 2022).

The physiological impact of HS extends to haematological parameters, reflecting the adaptive responses of dairy cows to thermal stress. Studies have highlighted significant reductions in red blood cell counts, haemoglobin levels, and haematocrit values, indicating disruptions in erythropoiesis and immune functionality (Burhans *et al.*, 2022). According to S.H. Siddiqui *et al.* (2022), heat stress significantly affects immune responses by altering immunoglobulin levels and disrupting energy

metabolism. Prolonged exposure to elevated temperatures has been shown to reduce IgM levels, indicating impairments in humoral immunity. Additionally, activation of the hypothalamic-pituitary-adrenal axis leads to increased glucocorticoid production, exerting immunosuppressive effects. This results in a reduction of T-lymphocyte counts and overall physiological deterioration during heat stress, increasing susceptibility to infectious diseases. Such disruptions compromise the ability of dairy cows to mount effective immune responses, making them more vulnerable to bacterial and viral infections, which can further exacerbate production losses and welfare concerns. Furthermore, the heightened metabolic demands during HS exacerbate oxidative stress, impairing immune responses and increasing susceptibility to diseases, including mastitis and metritis (Sachuk *et al.*, 2018; Scerri *et al.*, 2023).

Given the projected intensification of heat waves due to global warming, addressing HS in dairy cows has become a priority for sustainable livestock management. There has been a growing emphasis on non-invasive methods for assessing heat stress in animals. Non-invasive methodologies such as bioclimatic thermal indices and biomarker-based approaches, including cortisol analysis, offer valuable tools for quantifying the impact of HS and understanding adaptive mechanisms (Reolon *et al.*, 2024). As noted by G. Hoffmann *et al.* (2021) and S. Farafonov *et al.* (2024), blood parameters continue to serve as reliable biomarkers for assessing the state of the body under hyperthermia, reflecting the adaptive responses of dairy cows to thermal stress. Studies by D.S. Park *et al.* (2021) reported a significant decrease in red blood cell count, haemoglobin levels, and haematocrit values, indicating impaired erythropoiesis and immune function. B. Yadav *et al.* (2024) highlighted that chronic heat exposure induces significant alterations

in both innate and adaptive immune responses, ultimately leading to systemic immunosuppression. Prolonged exposure to elevated temperatures results in a decline in white blood cell counts, reductions in neutrophil and lymphocyte populations, and disruptions in mean corpuscular volume and haemoglobin levels. These haematological changes indicate a diminished capacity to mount effective immune defences, thereby increasing susceptibility to infections and inflammatory conditions. Moreover, chronic heat stress has been shown to downregulate key toll-like receptors (TLR2 and TLR4), which are essential for pathogen recognition and immune activation. Concurrently, a predominance of regulatory T cells (Tregs) fosters an anti-inflammatory environment that may further impair immune surveillance and host defence mechanisms. Such shifts towards an immunosuppressive state under prolonged heat stress underscore the physiological vulnerabilities associated with sustained hyperthermia and highlight the need for adaptive strategies to maintain immune homeostasis and overall resilience. These strategies are particularly crucial for improving the resilience of Holstein cows, which, due to their high metabolic rates, are especially vulnerable to thermal stress.

The purpose of this study was to investigate the haematological and immunobiological parameters of Holstein cows under prolonged heat stress. This research sought to identify specific changes in blood and immune parameters that reflected the cows' physiological and metabolic responses, contributing to the development of effective strategies for improving their health, productivity, and resilience under thermal stress conditions.

## Materials and Methods

Eighteen multiparous lactating Holstein cows in their second or third lactation were randomly assigned to one of two groups. The hyperthermia

group (HYP,  $n=8$ ) was studied during the summer season in August, while the control group (CON,  $n=10$ ) was studied during the autumn season in October. Days in milk (DIM) for cows in both groups ranged from 117 to 152 days. The differences in DIM (LSM  $\pm$  SE) between the HYP ( $130.2 \pm 3.13$ ) and CON ( $130.5 \pm 2.81$ ) groups were not statistically significant. The average daily milk yield (LSM  $\pm$  SE) was  $24.6 \pm 0.45$  kg in the CON group and  $24.8 \pm 0.48$  kg in the HYP group, with no significant differences observed between groups. This study was conducted in accordance with the principles of the European Convention for the Protection of Vertebrate Animals Used for Experimental and Other Scientific Purposes (1986) and approved by the Commission on Bioethics of the Dnipro State Agrarian and Economic University (protocol No. 5 dated 29 May 2018) and the requirements for humane treatment of animals.

The study was conducted on a commercial dairy farm located in the Dnipropetrovsk Oblast, Ukraine ( $48^{\circ}28'44''$  N,  $35^{\circ}36'46''$  E). Dairy cows were housed in a naturally ventilated barn using a loose housing system. Sand was utilised as bedding in the cubicles, providing improved hygiene and comfort for the animals. All cows were fed a corn silage-based total mixed ration (TMR) throughout the year. The diets were balanced for essential nutrients following the National Research Council (2001) guidelines. The TMR composition included high-quality feedstuffs such as barley, oat, and corn grains, alfalfa silage, cereal hay, wheat straw, rapeseed, sunflower, and soybean meals, as well as dried beet pulp and mineral-vitamin supplements. The ingredients were thoroughly mixed in specialised mixers equipped with electronic scales to ensure homogeneity. Feeding frequency and rationing were monitored and controlled using a computerised system. The barn was equipped with a feeding alley and six water troughs, which were freely accessible to the cows,

ensuring constant availability of feed and water. This housing and feeding setup provided optimal conditions to maintain the physiological state and productivity of the animals.

The thermal environment within the barn was monitored using a thermohygrometer (Benetech GM 1360, Shenzhen Jumaoyuan Science and Technology Co., Ltd., Shenzhen, China). Key environmental parameters, such as air temperature and relative humidity, were recorded to calculate the temperature-humidity index (THI), which served as an indicator of heat stress (HS). The THI was determined using Kibler's (1964) formula (Mylostyvyi *et al.*, 2023). Blood sampling from HYP animals occurred on the 5<sup>th</sup> day of a recurring heatwave that lasted 10 days, with heat stress conditions persisting for a continuous period of 45 days prior to sampling. This period included multiple heatwaves, the most recent lasting 5 days, and a more distant heatwave lasting 9 days. At the time points of blood sampling from HYP cows, the minimum THI in the barn was 77.9, with values ranging from 77.9 to 78.6. Daily air temperatures during the HYP period reached a maximum of 34°C, accompanied by low relative humidity (26%). Conversely, in October, the control (CON) group was maintained under thermal comfort conditions, with a THI consistently below 68. Blood samples were collected 42 days after the last heat wave (lasting 8 days) and 21 days after the last day with heat stress conditions (THI  $\geq$  72). During the control period, maximum daily air temperatures reached 19°C, with relative humidity ranging between 30% and 35%, corresponding to a THI of 63.1. These differences in climatic conditions between the experimental periods provided a basis for evaluating the impact of environmental stress on leukocyte indices and other physiological parameters.

Blood samples were collected via jugular vein puncture and directly transferred into 2-mL EDTA Vacutainer® tubes (Aichele Medico AG,

Basel, Switzerland). For serum preparation, whole blood was drawn into Vacutainer® serum tubes without anticoagulants. Complete blood counts (CBC) were conducted using an automatic haematology analyser, Sysmex XS-1000i (Sysmex Corporation, Japan). The CBCs included the determination of total white blood cell (WBC) count, red blood cell (RBC) count, haemoglobin (HGB) concentration, haematocrit (HCT), mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH), mean corpuscular haemoglobin concentration (MCHC), red cell distribution width (RDW-CV and RDW-SD), platelet (PLT) count, mean platelet volume (MPV), platelet distribution width (PDW), and plateletcrit (PCT).

The erythrocyte sedimentation rate (ESR) was measured using the Westergren method, which involves assessing the rate of erythrocyte sedimentation in a vertically positioned tube containing sodium citrate as an anticoagulant. Circulating immune complexes (CICs) were determined using the selective precipitation method with a polyethylene glycol-6000 solution (Hašková *et al.*, 1978). Serum immunoglobulin concentrations of classes A, G, and M (IgA, IgG, and IgM) were measured using an automatic biochemical analyser, Cobas Integra 400 Plus (Hoffmann-La Roche Ltd, Switzerland).

Serum lysozyme activity (SLA) and serum bactericidal activity (SBA) were evaluated using the photoelectric colorimetric method (Vlizo *et al.*, 2012). SLA was determined based on the method of A.G. Dorofeychuk, with modifications to the temperature conditions of the reaction between cow serum and the *Micrococcus lysodeikticus* culture in phosphate buffer. SBA was assessed using the Michel Tefler method, as modified by O.V. Smirnova and T.A. Kuzmina, with a test culture of *E. coli*.

Initially, the data were presented as mean values (Mean) and the standard error of the mean (SE). Since the distribution of most indicators did not meet normality criteria, non-parametric

statistical methods were employed for further analysis. Statistical processing was carried out using Statistica 12 (StatSoft, Inc., Tulsa, OK, USA). Significant differences between samples were determined by the Mann-Whitney U test, and the probability level of  $P < 0.05$  was considered significant.

## Results and Discussion

Under prolonged HS (HYP group), significant changes were observed in haematological and

immunobiological indicators compared to the CON group. WBC increased by 18% in the HYP group (Table 1), reflecting immune response activation under elevated THI conditions. HGB levels were 11% lower in HYP compared to CON ( $P < 0.05$ ), indicating potential disruptions in erythropoiesis or reduced erythrocyte lifespan. RBC counts and HCT values declined by 14.5% and 8.4%, respectively, in the HYP group, suggesting a decrease in circulating erythrocyte volume.

**Table 1.** Haematological indicators ( $M \pm SE$ )

Indicator	Experimental groups		p-value
	HYP	CON	
WBC, $\times 10^9/L$	11.80 $\pm$ 4.01	10.00 $\pm$ 1.52	0.2144
HGB, g/L	87.90 $\pm$ 10.35	98.80 $\pm$ 16.99	0.0351
RBC, $\times 10^{12}/L$	5.42 $\pm$ 0.67	6.34 $\pm$ 0.63	0.0051
HCT, %	24.24 $\pm$ 4.18	26.47 $\pm$ 2.80	0.1939
MCV, fL	44.57 $\pm$ 3.47	40.90 $\pm$ 3.01	0.0086
MCH, pg	16.17 $\pm$ 0.76	16.21 $\pm$ 0.75	0.9769
MCHC, g/L	366.80 $\pm$ 38.11	357.50 $\pm$ 51.28	0.9774
RDW-CV, %	15.12 $\pm$ 1.50	24.93 $\pm$ 1.60	0.0000
RDW-SD, fL	23.77 $\pm$ 4.16	33.10 $\pm$ 2.73	0.0008
PLT, $\times 10^9/L$	394.10 $\pm$ 95.16	257.58 $\pm$ 82.82	0.0008
MPV, fL	6.03 $\pm$ 0.26	7.56 $\pm$ 0.44	0.0000
PDW, %	14.41 $\pm$ 0.20	8.67 $\pm$ 1.28	0.0000
PCT, %	0.23 $\pm$ 0.05	0.22 $\pm$ 0.02	0.5208
ESR, mm/h	2.17 $\pm$ 0.39	3.16 $\pm$ 0.13	0.0251

*Source: developed by the author*

MCV increased by 8.9% ( $P < 0.05$ ), indicative of macrocytosis likely caused by metabolic or hydration disturbances. Variability in erythrocyte volume (RDW-CV and RDW-SD) decreased by 39% and 28%, respectively ( $P < 0.05$ ), suggesting adaptive mechanisms in haematopoiesis under stress. PLT rose by 53% ( $P < 0.05$ ), while MPV decreased by 20% ( $P < 0.05$ ), reflecting intensified production of smaller platelets. PDW increased 1.7-fold, suggesting enhanced coagulation mechanisms in response to vascular damage or inflammation. ESR in the HYP group was 31% lower than in CON, likely due to dehydration.

The immune response to prolonged HS involves complex adaptive mechanisms that regulate both humoral and cellular components. Changes in immune enzyme activity and antimicrobial defence reflect the body's attempt to maintain immune homeostasis under adverse environmental conditions. The impact of prolonged HS on immunobiological parameters was also significant (Table 2). SLA decreased by 48% ( $P < 0.05$ ) in the HYP group, indicating reduced innate immune activity during HS.

Conversely, SBA increased by 24%, likely as a compensatory response to maintain systemic

defence. This shift in enzymatic activity suggests an adaptive mechanism aimed at counterbalancing the decline in lysozyme-mediated protection by enhancing serum bactericidal capacity. In parallel, changes in CIC and immunoglobulin levels reflect alterations in humoral

immunity. CIC levels rose by 36%, indicating increased antigen release associated with cellular damage. Immunoglobulin levels (Ig A, Ig G, and Ig M) showed minimal differences between groups, with Ig A in HYP increasing by 43%, suggesting an adaptive immune response.

**Table 2.** Immunobiological indicators (M ± SE)

Indicator	Experimental groups		p-value
	HYP	CON	
Ig A, g/L	0.43 ± 0.26	0.31 ± 0.09	0.6904
Ig G, g/L	1.22 ± 0.09	1.17 ± 0.04	0.5476
Ig M, g/L	0.05 ± 0.01	0.05 ± 0.03	0.6904
CIC, AU	5.15 ± 1.70	3.78 ± 1.82	0.1811
SLA, %	22.99 ± 19.87	43.82 ± 16.36	0.0137
SBA, %	53.57 ± 20.17	43.16 ± 12.47	0.2029

*Source: developed by the author*

Prolonged HS in Holstein cows induces significant alterations in haematological and immunobiological blood parameters, reflecting the systemic response to elevated THI conditions. The reduction in HGB levels and RBC counts suggests suppressed erythropoiesis, shortened erythrocyte lifespan, or haemodilution due to increased water intake for thermoregulation. Concurrently, an increase in MCV indicates metabolic adjustments or hydration changes aimed at maintaining oxygen transport. Enhanced platelet activity, marked by increased PLT counts and structural modifications, highlights coagulation system activation in response to stress.

Further supporting these observations, V. Sejian *et al.* (2022) highlighted that HS exacerbates oxidative stress, with elevated markers such as malondialdehyde (MDA) and reduced activity of superoxide dismutase (SOD). These alterations in oxidative stress markers are indicative of the systemic strain imposed by HS, and the resulting oxidative damage contributes to decreased erythropoiesis and compromised metabolic function. This aligns with the results of O.M. Azeez *et al.* (2022), who reported similar

haematological changes in other livestock under heat stress, showing that oxidative stress plays a central role in HS-induced health issues.

PLT activity showed marked changes under HS conditions, with an increase in PLT count and a decrease in MPV, suggesting intensified production of smaller platelets. The elevation in PDW indicates enhanced coagulation mechanisms, likely triggered by vascular damage or inflammatory responses, as described by O.A. Saeed *et al.* (2021). These findings underscore the organism's effort to maintain haemostasis and prevent excessive blood loss under stress, a mechanism observed across several studies, including those by J.-H. Jo *et al.* (2021).

Immunobiological parameters revealed a distinct pattern of adaptation to HS. The significant reduction in SLA, indicative of innate immune suppression, was observed alongside an increase in SBA, reflecting compensatory mechanisms to preserve immune defence (Min *et al.*, 2023). Elevated CIC levels also reflected immune activation associated with cellular damage due to HS, supporting the findings of V. Tejaswi *et al.* (2020), who noted similar immune

responses under thermal stress. These findings suggest that HS not only disrupts erythropoiesis but also triggers a complex immune response, which includes both suppression and activation of immune functions in an attempt to mitigate damage and preserve overall health.

Minimal variations in Ig A, Ig G, and Ig M levels, despite an observed increase in Ig A, suggest that adaptive immune responses stabilise over prolonged HS exposure. This stabilisation aligns with observations by S.L. Cartwright *et al.* (2021), who reported that high immune responders in Holstein cows demonstrated improved thermoregulation and cellular protection during HS, possibly due to enhanced expression of HSP70. This highlights the long-term nature of HS-induced immune modulation and suggests that dairy cattle may develop adaptive responses over time, depending on their individual immune capacity.

Findings by A. Rebl *et al.* (2020) and H. Kim *et al.* (2024) corroborated this, indicating that chronic HS leads to metabolic shifts and immune adaptations that help animals to cope with thermal challenges. For example, changes in blood metabolites, including increased HSP70 levels, were observed as protective responses to oxidative stress and cellular damage. However, these adaptations are not limitless, as prolonged exposure to high temperatures may ultimately compromise immune function and metabolic homeostasis, reducing productivity and increasing vulnerability to diseases (Steele, 2016). This is supported by findings from B. Stefanska *et al.* (2024), who reported similar effects of heat stress on immunometabolic indices during the close-up dry period in dairy cows.

Moreover, T.M. Scerri *et al.* (2023) highlighted the importance of environmental management in alleviating the negative effects of HS on dairy cattle. Strategies such as providing shade, cooling systems, and nutritional supplementation reduce the impact of HS, supporting both immune

function and productivity. Similarly, R. Mylostvyi *et al.* (2023) demonstrated that improving microclimate conditions within barns, particularly during high THI periods, mitigates the adverse effects of HS on milk yield and quality.

The increase in CICs, as reported by K. Pawlak-Osińska *et al.* (2019), further supports the idea that HS activates a compensatory immune response. This activation is associated with the release of antigenic components and subsequent CIC formation, playing a crucial role in systemic immune defence during HS. Additionally, alterations in gut microbiota composition and immune-related gene expression observed in sturgeons (Yang *et al.*, 2022) and juvenile greater amberjacks (Hao *et al.*, 2024) suggest that HS not only affects systemic immunity but also influences the microbiome, which is essential for maintaining homeostasis and overall health.

In conclusion, prolonged HS induces a multifaceted response in dairy cows, affecting both haematological and immune systems. The adaptive changes observed in RBC and WBC counts, along with variations in PLT and immune function, highlight the complex interplay between stress-induced metabolic shifts, oxidative damage, and immune modulation. The elevation in CICs and the reduction in innate immunity markers further emphasise the systemic adaptations to HS, providing valuable insights into the physiological challenges faced by dairy cows under elevated THI conditions. These results underscore the importance of integrated management strategies, including environmental cooling, nutritional support, and breed selection, to mitigate the negative impacts of HS and enhance the welfare and productivity of dairy cattle.

## Conclusions

Prolonged heat stress significantly alters the haematological and immunobiological parameters of Holstein cows, reflecting the

physiological strain associated with elevated temperature-humidity index conditions. The study revealed a 14.5% reduction in red blood cell count, an 11% decrease in haemoglobin concentration, and an 8.4% decline in haematocrit in heat-stressed cows compared to the control group ( $P < 0.05$ ). These findings suggest impaired erythropoiesis, reduced erythrocyte lifespan, or haemodilution as a compensatory mechanism for thermoregulation. Concurrently, an 8.9% increase in mean corpuscular volume indicates possible metabolic adjustments or alterations in hydration status, while a 53% elevation in platelet count and a 20% decrease in mean platelet volume suggest intensified coagulation processes, possibly in response to vascular damage.

Changes in immune function were also evident. Serum lysozyme activity, an important component of innate immunity, was 48% lower in the heat-stressed group, indicating immune suppression ( $P < 0.05$ ). Moreover, circulating immune complex levels increased by 36%, reflecting antigen release and potential inflammatory responses associated with cellular damage. Immunoglobulin levels did not show significant differences between groups, although a notable increase in IgA suggests an adaptive immune response.

These findings highlight the physiological trade-offs Holstein cows experience under prolonged heat stress. The decline in erythropoiesis and immune activity may increase susceptibility to metabolic imbalances and inflammatory

processes. To mitigate these effects, targeted nutritional interventions, such as antioxidant and amino acid supplementation, may support immune resilience and haematopoiesis. Additionally, improved environmental management strategies, including optimal ventilation, shading, and water cooling systems, can help to reduce the physiological burden of heat stress and maintain homeostasis.

Further research is required to investigate the long-term consequences of heat stress on immune resilience and haematopoiesis. Future studies should also focus on nutritional and environmental strategies to mitigate heat stress, including dietary interventions aimed at supporting erythropoiesis and immune function, and optimising barn microclimate and cooling systems. In addition, evaluating oxidative stress markers and their correlation with haematological changes may provide further insights into the mechanisms underlying heat stress adaptation.

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### **Conflict of Interest**

None.

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## Вплив тривалого теплового стресу на гематологічні показники голштинських корів

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**Анотація.** Тривалий тепловий стрес є серйозним викликом для продуктивності та здоров'я голштинських корів через їх підвищену чутливість до високих температур та інтенсивний метаболізм. Метою дослідження було вивчення змін гематологічних та імунобіологічних показників у голштинських корів за тривалого теплового стресу. У дослідженні використовували 18 корів другої-третьої лактації, з яких були сформовані дві групи. Одну групу в літній період (серпень) в умовах гіпертермії (НУР, n = 8), іншу – за комфортних умов восени (жовтень), яку вважали за контрольну (CON, n = 10). Аналіз показників крові проводили за допомогою загальноприйнятих у клінічній ветеринарній практиці методів. Результати продемонстрували значне зниження кількості еритроцитів (на 14,5 %), рівня гемоглобіну (на 11 %) та гематокриту (на 8,4 %) у корів НУР у порівнянні з групою CON ( $P < 0.05$ ), що свідчить про порушення еритроцитопоезу або зниження тривалості функціонування еритроцитів. Водночас спостерігалось підвищення середнього обсягу еритроцитів (на 8,9 %) та кількості тромбоцитів (на 53 %) за зниження середнього обсягу тромбоцитів (на 20 %), що вказує на адаптаційні метаболічні та коагуляційні реакції організму. Зниження активності лізоциму сироватки крові (на 48 %) поряд із підвищенням рівня циркулюючих імунних комплексів (на 36 %) свідчить про пригнічення вродженого імунітету та активацію компенсаторних механізмів імунного захисту. Практична цінність дослідження полягає у виявленні потенційних біологічних маркерів для моніторингу та управління тепловим стресом, що сприятиме покращенню здоров'я та продуктивності молочних корів

**Ключові слова:** молочна худоба; гіпертермія; показники крові; еритропоез; природна резистентність