DOI: 10.37000/abbsl.2026.118.15
UDC: 636.2.085.3:591.133

Dmytro Chabanenko,
PhD student, Dnipro State Agrarian and Economic University,
S. Efremov Str., 25, Dnipro, 49600, Ukraine
ORCID ID: 0009-0000-1898-5010
e-mail: 11590948@student.dsau.dp.ua

Roman Shynkarenko,
PhD student, Dnipro State Agrarian and Economic University,
S. Efremov Str., 25, Dnipro, 49600, Ukraine
ORCID ID: 0009-0003-3819-6539
e-mail: 12286177@student.dsau.dp.ua

CORRELATION BETWEEN KEY BLOOD BIOMARKERS (BETA-HYDROXYBUTYRATE, GLUCOSE, LIPOPROTEINS) AND HAEMATOLOGICAL PARAMETERS IN BROWN SWISS COWS HOUSED IN A NATURALLY VENTILATED BARN

Abstract

This study examined the correlations between key biomarkers of energy and lipid metabolism (beta-hydroxybutyrate, glucose, lipoproteins) and haematological and biochemical blood parameters in Brown Swiss cows kept under year-round housing in a naturally ventilated barn. The relevance of this research is due to the increasing frequency of metabolic disorders and heat stress in high-yielding dairy cattle, which is exacerbated by seasonal fluctuations in microclimatic conditions. The investigation of the diagnostic value of blood biomarkers is considered promising for the early detection of metabolic stress and for improving the effectiveness of animal welfare monitoring. The study involved second-lactation cows (n = 50) at one of the largest Brown Swiss dairy complexes in central Ukraine. Representative groups of cows were randomly formed for each season, ensuring similar productivity and stage of lactation. Protein, lipid, carbohydrate and mineral metabolism, as well as haematopoietic indices, were investigated. Environmental conditions (temperature, humidity, temperature–humidity index) were assessed using data from the nearest meteorological station. Correlations between blood parameters were determined using Spearman's correlation coefficient. Data processing and statistical analysis were performed using Statistica 12 (StatSoft Inc., USA), with significance accepted at $p \leq 0.05$. The results showed that beta-hydroxybutyrate was significantly negatively correlated with liver enzyme activity (ALT, $r = -0.465$, $p < 0.05$; AST, $r = -0.321$, $p < 0.05$). Glucose was negatively correlated with total calcium ($r = -0.742$, $p < 0.05$), Ca/P ratio ($r = -0.561$, $p < 0.05$), haematocrit ($r = -0.472$, $p < 0.05$), total lipoproteins ($r = -0.512$, $p < 0.05$) and albumins ($r = -0.283$, $p < 0.05$), but positively correlated with inorganic phosphorus ($r = 0.309$, $p < 0.05$), MCH ($r = 0.333$, $p < 0.05$) and MCHC ($r = 0.385$, $p < 0.05$). Lipoproteins showed positive correlations with total calcium ($r = 0.532$, $p < 0.05$), carotene ($r = 0.399$, $p < 0.05$), haematocrit ($r = 0.417$, $p < 0.05$), Ca/P ratio ($r = 0.294$, $p < 0.05$) and negative correlations with AST ($r = -0.302$, $p < 0.05$) and MCHC ($r = -0.306$, $p < 0.05$). The identified significant correlations between the *principal biomarkers and haematological parameters reflect the integrated regulatory mechanisms of homeostasis. The findings confirm the utility of simultaneous monitoring of beta-hydroxybutyrate, glucose and lipoproteins in blood for assessing metabolic adaptation and the risk of disorders in contemporary dairy cow management systems.*

Keywords: *Brown Swiss cows, biomarkers, haematological and biochemical blood parameters, correlation, adaptation, microclimate.*

Introduction. Under modern conditions of industrial milk production, there is a continuous increase in the functional load on the bodies of high-yielding cows, which raises their vulnerability to the impact of environmental and technological stress factors [1, 2]. The introduction of year-round housing of animals in naturally ventilated barns further strengthens the dependence of the microclimate on fluctuations in external weather conditions. This issue is particularly relevant in the context of global climate change, which leads to an increase in the frequency and duration of heat waves, in turn causing a deterioration in health, a decline in milk yield, disruption of reproductive functions and a higher incidence of disease in dairy cows [3–5].

In these circumstances, there is a growing need for accurate assessment of the physiological state of animals to enable timely identification of stressors and prevention of economic losses. One of the promising directions is the search for and use of reliable biomarkers capable of reflecting both acute and chronic changes in the bodies of cows in response to meteorological fluctuations [6–8]. Among the various physiological parameters, blood indicators are traditionally regarded as the most informative markers of the clinical status of animals and their response to stress and technological factors [9–11].

The biochemical profile of blood makes it possible not only to monitor adaptation to housing conditions but also to identify early signs of metabolic disturbances, which are of key importance for maintaining welfare and productivity [1, 12]. Under conditions of persistent load on organs and systems, and an increased risk of heat stress and its negative consequences, the issue of identifying reliable biomarkers for evaluating the physiological state and adaptation of animals becomes particularly relevant [13]. Further elucidation of the problem allows for the detailing of current understanding of the mechanisms of biochemical changes in blood indices, with an emphasis on the informativeness of such biomarkers as beta-hydroxybutyrate, glucose and lipoproteins for assessing physiological adaptation in cows under modern milk production systems.

Review of recent studies and publications. Подібно до багатьох паразитарних інфекцій, еймеріоз вражає в основному молодняк, що пов'язано з розвитком у курчат імунітету в постнатальний період. На думку багатьох дослідників, на кокцидіоз хворіють курчата з 10-добового до 3-місячного віку [15, 23].

The functioning of the bodies of high-yielding dairy cows under conditions of intensive production is determined by the balance between energy intake, its redistribution for the maintenance of homeostasis, and productive output. Under year-round loose housing, seasonal fluctuations in the microclimate and photoperiod manifest as behavioural and metabolic changes [14]. In these circumstances, key blood biomarkers may serve as integral indicators of animal adaptation, reflecting the synergy of energetic, immune, and oxidative shifts in the maintenance of homeostasis [15–17].

Beta-hydroxybutyrate (BHB) is considered a principal marker of changes in energy status, allowing for the identification of negative energy balance at early stages and serving as a predictor of metabolic disturbances in high-producing cows. Its elevation is observed both under conditions of intensive lactation and in response to heat stress, when the need for mobilisation of alternative energy sources increases. In the case of heat stress (HS), such a response is regarded as a universal adaptive mechanism aimed at temporarily maintaining energy homeostasis by mobilising alternative energy reserves [18–21]. In dairy cows, reduced feed intake and enhanced lipolysis during periods of heat are accompanied by a rise in BHB, which is regarded as an early marker of metabolic strain and the risk of ketosis [1]. These changes are especially pronounced in the postpartum period, when the combination of high productive load and physiological limitations of energy intake are most acute; in the summer season, an increase in BHB in cows is associated with a higher risk of negative energy balance and requires constant monitoring [22]. The diagnostic significance of this indicator is also confirmed by its prognostic role: increased BHB levels at the early stages of lactation are associated with a reduction in milk yield, increased morbidity and reduced fertility [23].

At the same time, seasonal factors may shape the ketogenic response even outside classic HS conditions. For example, in cold, high-altitude environments during winter, increased BHB has been associated with energy deficiency and low feed availability, also reflecting the adaptive nature of ketogenesis [24]. However, there are reports of alternative scenarios of energy metabolism reorganisation. For example, a transition from thermoneutral conditions to moderate–severe HS has been described to result in a reduction in BHB levels, which researchers interpreted as a change in the priorities of energy supply and redistribution between glucose and lipid substrates [10]. This highlights the necessity of interpreting BHB in the context of other metabolic indicators. Recent studies have demonstrated that in both acute and chronic HS, BHB levels in cows rise in parallel with disturbances in carbohydrate metabolism and hormonal regulation, which allows it to be considered an early marker of metabolic strain and a predictor of subclinical disorders [8, 25, 26].

Glucose is a component of energy metabolism in cows, supplying tissues with high demands and serving as the main precursor of lactose, which directly links it to milk productivity [27]. As a biological marker, it is sensitive to changes in feeding and temperature regime. In particular, a decrease in glucose level during HS reflects the increased use of the body's energy reserves and may be accompanied by the activation of catabolic processes and enhanced ketogenesis. Under the influence of HS, hormonal regulation of glycaemia is disturbed, glucose use by peripheral tissues is altered and energy flows are redistributed, which lowers metabolic efficiency [27]. An increase in environmental temperature is accompanied by reduced appetite and feed intake, which leads to a drop in glucose concentration and activation of compensatory energy pathways [6]. In dairy cows, depending on their level of heat tolerance, the decrease in glucose is more pronounced in heat-sensitive animals and is regarded as a stable systemic indicator of maladaptation to thermal load [7]. In general, hypoglycaemia during heat is seen as the result of reduced energy intake combined with increased expenditure on thermoregulation, and has been confirmed in numerous studies in cows and ruminants of various breeds [21, 28–31]. However, seasonal glucose dynamics are also observed in the cold period, when its decrease is associated with increased energy expenditure for thermoregulation, which confirms the universality of glucose as a marker of energy status [24, 32]. High-yielding cows often demonstrate lower glycaemia due to intensive use of glucose for lactose synthesis, which simultaneously reflects adaptation to metabolic load and the risk of metabolic disorders [33]. It has also been shown that HS in dairy cows is accompanied by a reduction in glucose, enhanced ketogenesis, and alterations in lipid metabolism, with the magnitude of these changes depending on the duration and intensity of stress [29, 34].

Lipoproteins reflect the state of lipid transport and hepatic metabolism and are sensitive to seasonal and stress-induced shifts in energy balance. Increases in environmental temperature are associated with changes in the plasma lipid profile, in particular a reduction in total lipoproteins, reflecting the redistribution of energy resources and enhanced fat catabolism [35]. Similar changes have been described under HS in cows and bulls, where the decline in lipoproteins has been associated with disturbances in hepatic lipid synthesis and transport, and overall metabolic reorganisation [21, 28, 36]. Researchers have also noted that HS leads to a reduction in total lipoproteins, a shift in the balance of free fatty acids towards mobilisation of energy substrates and the activation of lipid oxidation processes, which is accompanied by an increased risk of oxidative stress [12, 34]. Given that lipoproteins are the transport form for fat-soluble antioxidants such as β-carotene and vitamin E, their reduction under stress conditions may also reflect a weakening of the antioxidant defence of the body [37]. Changes in lipoproteins are closely linked to the mineral and general metabolic status of animals, which confirms the value of comprehensive blood assessment during periods of high metabolic load [38–40]. Under metabolic stress and endotoxaemia, a reduction in lipoproteins occurred in parallel with a decrease in antioxidant potential, which further highlights the importance of lipid metabolism markers in the assessment of the adaptive response [41].

Taken together, the data suggest that BHB, glucose and lipoproteins form a functionally related set of biomarkers, reflecting energy status, the intensity of reserve mobilisation, and the efficiency of transport systems in the blood. In most studies, HS and seasonal temperature fluctuations are associated with increased BHB and decreased glucose and lipoproteins, which is consistent with a state of negative energy balance with activation of ketogenesis and restructuring of lipid metabolism [29, 42]. Our previous studies [9, 43] have shown that such blood indicators as BHB, glucose, and total lipoproteins exhibited significant seasonal variation, supporting the rationale for their monitoring and investigation of their relationships with other blood metabolites for assessing the metabolic status of cows under modern housing systems [5, 11, 44].

The **aim** was to determine the correlations between key biomarkers of energy and lipid metabolism (beta-hydroxybutyrate, glucose, total lipoproteins) and morpho-biochemical blood parameters in Brown Swiss cows under year-round loose housing.

Presentation of the main research findings. The research was conducted in 2025 at the “Yekaterynoslavsky” Dairy Production Complex LLC, which is the largest facility in Europe for the breeding of Brown Swiss cattle. All experimental procedures complied with the requirements of the European Convention for the Protection of Vertebrate Animals Used for Experimental and Other Scientific Purposes (Strasbourg, France, 1986) and the Law of Ukraine “On the Protection of Animals from Cruelty” (Kyiv, 2006). Morphological and biochemical blood analyses were carried out at the “Biosafety Center” Research Facility of Dnipro State Agrarian and Economic University within the framework of approved research topics (state registration numbers 0123U101593 and 0124U001457).

In each season, four groups of second-lactation Brown Swiss cows were randomly formed (winter, n = 10; spring, n = 10; summer, n = 15; autumn, n = 15) based on the principle of analogues (physiological state, lactation stage and number, average daily milk yield). The cows were housed loose in cubicles in a naturally ventilated building. Throughout the year, all cows received a total mixed ration (TMR) based on maize silage (silage 60%, soybean meal 22%, wheat bran 13.5%, sodium chloride 1%, sodium bicarbonate 1%, vitamin-mineral supplement up to 1%), balanced according to the recommendations of the National Research Council (NRC, 2001).

Data on air temperature (°C) and relative humidity (%) were obtained from the nearest meteorological station, freely available on the official website of the Ukrainian Hydrometeorological Centre. For each parameter, data were recorded every three hours throughout the year (2920 records). Meteorological data were systematised and the temperature-humidity index (THI) was calculated using the method described by Mylostyvyi and Izhboldina [45]. The housing included feed alleys and group drinkers with free access. Housing and husbandry conditions were assessed using standard zoohygienic methods [46].

Blood samples were collected from the jugular vein in the early morning (06:00–07:00) before feeding, using vacuum tubes without anticoagulant for biochemical tests and with EDTA for haematological analysis. Immediately after sampling, the blood was transported to the laboratory in refrigerated containers (+4 °C). Serum was separated by centrifugation at 3000 rpm for 10 minutes. Analyses were conducted on fresh blood samples within two hours of collection.

Haematological studies were carried out according to standard veterinary practice [47]. Biochemical parameters (total protein, urea, blood urea nitrogen, creatinine, aspartate aminotransferase (AST), alanine aminotransferase (ALT), alkaline phosphatase, glucose, total calcium, inorganic phosphorus, carotene, total lipoproteins, and beta-hydroxybutyrate) were determined using a BioSystem A25 automatic analyser (Spain) with certified diagnostic reagent kits produced by Filisit-Diagnostika (Ukraine), Cormay (Poland), and Spinreact (Spain). Protein fractions (albumin, α-, β-, and γ-globulins) were determined by agarose gel electrophoresis. Red blood cell indices were analysed using a Sysmex XS-1000i haematology analyser (Japan) according to the manufacturer's instructions and standard laboratory practice, as previously described [9].

Statistical processing of the results was performed in Statistica 12 (StatSoft Inc., USA). Data are presented as the median and 25th and 75th percentiles. Spearman's correlation coefficient was used to determine associations between parameters, with statistical significance set at 0.05. The coefficient of variation (CV, %) was used to assess the variability of indicators.

Since the cows were fed a total mixed ration (TMR) throughout the year, this ensured the stability of feeding and minimised the influence of nutritional factors on the studied biochemical and haematological parameters. Under such conditions, the main factor determining the physiological state of the animals was the weather, which varied by season and created a differentiated background of adaptation.

It was found that during the winter period, the mean ambient temperature was –0.5 °C (ranging from –10.0 to +7.1 °C), the relative humidity was 80.4% (50.4–97.9%), and the maximum temperature-humidity index (THI max) averaged 38.8 (25.6–50.4). At the time of blood sampling, the ambient temperature was –1 °C, humidity was 89%, and THI max was 31.9, which characterised conditions of minimal thermal load. The low THI values during this period created near-thermoneutral conditions, where physiological systems functioned without additional thermal stress, and the blood parameters could be considered a baseline reference for assessing seasonal adaptation shifts.

In spring, the average temperature increased to +10.5 °C (from –1.4 to +21.1 °C), relative humidity decreased to 62.0% (32.3–96.3%), and THI max reached an average of 58.5 (37.6–70.9). At blood sampling, the temperature was +12.4 °C, humidity was 51%, and THI max was 54.6, corresponding to a transition to moderate thermal load. Under such conditions, gradual activation of thermoregulatory mechanisms and metabolic adaptation occurred, which, according to the literature [17, 35], is mainly reflected in changes in carbohydrate and lipid metabolism parameters.

During the summer season, the highest temperatures prevailed, with an average of +20.8 °C (14.5–26.9 °C), relative humidity was 62.8% (26.0–96.9%), and the maximum THI max reached 71.5 (61.5–79.8). At the time of blood sampling, the temperature was +23 °C, humidity was 40%, and THI max was 68.3, which indicated the presence of stress-related heat load on the cows. Under such conditions, heat stress acted as a key trigger for metabolic rearrangements, in particular for liver function, energy balance and haematopoiesis, and could alter the relationships between major blood biochemical markers [4, 48].

In autumn, the average temperature decreased to +10.6 °C (from –0.3 to +25.3 °C), while humidity increased to 78.5% (51.3–99.1%), and the average THI max was 56.1 (36.7–76.8). At the time of blood sampling, the air temperature was +11 °C, humidity was 94%, and THI max was 52.0, meaning moderate climatic conditions prevailed. The combination of lower temperatures and high humidity could maintain adaptive tension in the body after the summer heat stress and contribute to the persistence of certain metabolic shifts.

In general, during the year, the mean daily ambient temperature ranged from –10.0 °C to +26.9 °C, humidity from 26% to 99%, and THI max varied from 25.6 to 79.8 (annual average 56.3). Thus, blood sampling was conducted against the background of various seasonal weather scenarios, which allows the observed changes in biochemical and haematological parameters to be considered as a reflection of the integrated physiological adaptation of cows to seasonally varying climatic pressure under year-round loose housing [6, 49].

The morpho-biochemical blood parameters provided a comprehensive reflection of the physiological status of the animals under year-round housing in a naturally ventilated barn. The obtained indicators made it possible to assess the coherence of protein, energy, mineral and enzymatic metabolism in the context of adaptation of the cows to variable seasonal microclimatic loads.

The protein metabolism in the cows studied was generally characterised by parameters within the physiological norm (Table 1), which indicates the maintenance of basic protein homeostasis under conditions of standardised feeding.

Table 1

Morpho-biochemical blood parameters of Brown Swiss cows, Median (25th–75th percentile); n = 50

Parameter	Median	25th–75th percentile	CV, %	Reference range
Protein metabolism				
Total protein, g/L	73	70 – 76	5.5	55–75
Urea, mmol/L	5.15	4.4 – 5.6	23.9	2.8–5.8
Urea nitrogen, mg%	9.8	8.4 – 10.7	23.9	8–14
Albumins, %	38.06	31.72 – 40.29	22.4	38–50
α-globulins, %	19.37	14.82 – 28.61	42.1	12–20
β-globulins, %	20.43	14.95 – 24.58	35.4	10–16
γ-globulins, %	20.21	15.02 – 26.86	34.7	25–40
Lipid metabolism				
Total lipoproteins, mg%	1258	1165 – 1421	16.8	400–800
Beta-hydroxybutyrate, mmol/L	0.43	0.34 – 0.56	35.5	up to 1.2
Carotene, mcg%	774.5	648 – 906	25.6	275–965
Carbohydrate metabolism				
Glucose, mmol/L	2.7	2.3 – 3.4	19.0	2.5–4.16
Mineral metabolism				
Total calcium, mmol/L	2.3	2.1 – 2.4	7.5	2.43–3.10
Inorganic phosphorus, mmol/L	1.8	1.6 – 1.9	11.5	1.45–1.94

Ca/P ratio, units	1.2	1.1 – 1.4	15.4	1.2–1.6
Enzyme activity				
AST, U/L	96	82 – 107	22.0	10–50
ALT, U/L	41.5	37 – 49	26.9	10–40
Alkaline phosphatase, U/L	84.5	68 – 99	35.2	20–150
De Ritis ratio (AST/ALT)	2.2	2.0 – 2.7	39.4	1.0–3.4
Functional liver tests				
Thymol turbidity test, units S-H	4.7	3.9 – 6.7	40.8	0–4
Blood cell indices				
Haemoglobin, g/L	108.5	102 – 117	10.1	80–150
Haematocrit, %	30.15	28.9 – 32.9	10.2	34–46
Erythrocytes, T/L	6.08	5.62 – 6.50	10.3	5.0–7.5
MCV, fL	51.38	48.47 – 53.11	7.5	40–60
MCH, pg	18.27	17.33 – 18.98	7.0	17–24
MCHC, ×10 g/L	35.63	34.28 – 37.01	5.5	30–36
Colour index, units	0.995	0.940 – 1.030	7.0	0.56–1.05
ESR, mm/h	1.0	1.0 – 1.0	34.4	up to 13
Platelets, G/L	350.5	249 – 389	31.8	100–750
Leukocytes, G/L	10.9	9.7 – 12.8	21.0	4–12

Note: MCV – mean corpuscular volume; MCH – mean corpuscular haemoglobin;

MCHC – mean corpuscular haemoglobin concentration; ESR – erythrocyte sedimentation rate. Data in the table represent the results of the authors' investigations.

A relatively low coefficient of variation in total protein content throughout the year indicates a generally homogeneous protein status of the herd, whereas much greater variability in urea and globulin fractions (notably, a decrease in γ-globulins by 9.5% below the lower reference limit) may reflect individual differences in protein metabolism and immune system tension in response to seasonal microclimate changes. Such dissociation between the stability of total protein and the variability of its fractions is considered a characteristic sign of adaptive processes under chronic or repeated climatic stressors [1, 49].

A reduction in the proportion of albumin to the lower reference range in some animals may indicate functional stress on the liver's protein-synthetic capacity. According to the literature, albumin is sensitive to changes in energy balance and heat load, which allows it to be regarded as an early marker of metabolic adaptation under stress conditions [36, 48].

The parameters of lipid metabolism were characterised by a trend towards elevated total lipoprotein levels compared to the physiological norm (by 1.4 to 1.7 times), probably due to dietary features and adaptation of lipid transport. The low coefficient of variation for this parameter indicates a generally homogeneous lipid metabolism in the herd. Meanwhile, a high variability in beta-hydroxybutyrate reflects different degrees of activation of ketogenesis, which may be associated both with individual features of energy metabolism and with the response to heat stress [19, 23].

Blood glucose levels in most cows remained within the physiological range, and the moderate coefficient of variation indicates overall stability in the herd's energy supply under uniform feeding. At the same time, individual deviations may reflect different sensitivities to seasonal temperature fluctuations and the realisation of alternative energy supply pathways, which is consistent with the concept of glucose as a central regulator of metabolic adaptation under heat stress [27, 33].

The mineral metabolism indicators, in particular total calcium, inorganic phosphorus, the Ca/P ratio, and carotene, were generally within reference values. Low variability in calcium and phosphorus suggests effective control of mineral homeostasis under standardised feeding, whereas higher variability in carotene may be due to individual differences in absorption of fat-soluble vitamins and feed components, which is often exacerbated under heat stress [37, 38].

Analysis of blood enzyme activity revealed that, in some animals, there was a tendency towards exceeding the reference values for AST (by 1.6 to 2.1 times) and ALT (by 1.2 times), which may be considered as a marker of metabolic load on the liver. High coefficients of variation for these enzymatic parameters indicate considerable individual variation in hepatocyte responses to microclimatic and other stress factors, which is typical for adaptation processes under abrupt temperature fluctuations [4, 10]. An increase in the thymol test in some cows (by 1.6 times above the reference value) additionally indicates possible disturbances in hepatic protein synthesis or a latent course of hepatopathies, and the significant variability of this parameter reflects different levels of functional liver adaptation in the herd.

Most erythrocyte indices remained within physiological ranges, and low coefficients of variation indicate stability in haematopoiesis processes under uniform housing conditions. However, moderate variability in platelets and ESR may reflect individual features of haemopoiesis and immune reactivity, which becomes particularly important under seasonal stress [11, 44].

Correlation analysis (Table 2) revealed both certain trends and significant associations between the key biomarkers (beta-hydroxybutyrate, glucose, lipoproteins) and other haematological and biochemical parameters. The identified relationships reflect the integrated nature of metabolic regulation in cows under year-round loose housing and seasonal variability in climatic load, which is in line with current views on the systemic adaptation of the organism to heat stress.

Table 2.

Correlation coefficients (r) between blood parameters

Parameter	Beta-hydroxybutyrate, mmol/L	Glucose, mmol/L	Total lipoproteins, mg%
Total protein, g/L	0.099	–0.026	0.162
Urea, mmol/L	–0.161	–0.092	–0.141
Urea nitrogen, mg%	–0.163	–0.093	–0.142
Creatinine, µmol/L	–0.106	–0.438*	0.243
AST, U/L	–0.321*	0.207	–0.302*
ALT, U/L	–0.465*	0.132	–0.215
De Ritis index (AST/ALT)	0.292*	–0.095	–0.003
Alkaline phosphatase, U/L	0.013	0.040	–0.051
Glucose, mmol/L	–0.062	—	–0.512*
Total calcium, mmol/L	0.129	–0.742*	0.532*
Inorganic phosphorus, mmol/L	–0.010	0.309*	–0.054
Ca/P, ratio	0.103	–0.561*	0.294*
Carotene, µg%	0.058	–0.218	0.399*
Total lipoproteins, mg%	–0.044	–0.512*	—
Thymol test, S-H units	–0.125	0.167	0.051
Beta-hydroxybutyrate, mmol/L	—	–0.062	–0.044
Albumin, %	0.079	–0.283*	0.098

α-globulins, %	–0.051	0.109	–0.219
β-globulins, %	–0.269	0.112	–0.001
γ-globulins, %	0.238	0.077	0.162
Haemoglobin, g/L	0.264	–0.242	0.251
Haematocrit, %	0.124	–0.472*	0.417*
MCH, pg	0.379*	0.333*	–0.192
MCHC, ×10 g/L	0.335*	0.385*	–0.306*
Platelets, G/L	0.244	–0.250	0.101
Leukocytes, G/L	0.044	–0.076	0.143

*Note: * indicates $p < 0.05$. Data are results of the authors' study.*

Among the main biochemical blood parameters, beta-hydroxybutyrate demonstrated a number of significant associations, reflecting its role in the systemic adaptation of cows to year-round loose housing in naturally ventilated facilities. Statistically significant negative correlations were recorded with the activity of liver enzymes AST ($r = –0.321$; $p = 0.0226$) and ALT ($r = –0.465$; $p = 0.0006$), indicating an inverse relationship between the intensity of ketogenesis and hepatocytic activity. A similar mechanism has been described in studies in which an increase in ketone bodies was associated with a decrease in the activity of hepatic enzymes against the background of seasonal metabolic shifts in the organism [43, 50]. A significant positive correlation with the De Ritis ratio ($r = 0.292$; $p = 0.0397$) confirms that an increase in the AST/ALT ratio is accompanied by more intensive ketogenesis, which can be interpreted as an adaptive response to changes in the microclimate and energy balance.

A significant association was found between the concentration of beta-hydroxybutyrate and the erythrocyte indices MCH ($r = 0.379$; $p = 0.0065$) and MCHC ($r = 0.335$; $p = 0.0175$), reflecting a possible role of ketone bodies in the regulation of oxygen transport and erythrocyte metabolism as part of compensatory responses under increasing hypoxia [44, 51]. Among the observed trends, negative correlations of this biomarker with beta-globulins ($r = –0.269$; $p = 0.0582$) and haemoglobin ($r = 0.264$; $p = 0.0641$) are also noteworthy, which, although not statistically significant, may indicate general mechanisms of interaction between ketone and protein metabolism. Similar trends have been associated with changes in the blood protein profile during periods of adaptation to heat stress, underlining the multifunctionality of ketone bodies in metabolism [35, 36].

Blood glucose also demonstrated both statistically significant and trending associations with metabolic and mineral markers. Significant negative correlations with creatinine ($r = -0.438$; $p = 0.0014$), total calcium ($r = -0.742$; $p < 0.0001$), Ca/P ratio ($r = -0.561$; $p < 0.0001$), total lipoproteins ($r = -0.512$; $p = 0.00014$), albumin ($r = -0.283$; $p = 0.0456$) and haematocrit ($r = -0.472$; $p = 0.0005$) indicate the complex influence of energy metabolism on protein, lipid and mineral homeostasis, which is consistent with other studies in cows and goats under heat stress [18, 27, 33]. A significant positive association was identified between glucose and inorganic phosphorus ($r = 0.309$; $p = 0.0287$), as well as with the erythrocyte indices MCH ($r = 0.333$; $p = 0.0179$) and MCHC ($r = 0.385$; $p = 0.0057$), suggesting the influence of glucose on haematopoiesis and oxygen transport. Similar associations and the role of glucose in maintaining erythropoiesis and erythrocyte function have also been confirmed in cattle under both stall and pasture conditions [6, 17].

Trends were observed in the relationships with carotene, beta-globulins and platelets, where the correlation coefficients suggested a possible influence of glucose on the vitamin and cellular composition of the blood, but statistical significance was not achieved. Weak associations between carbohydrate metabolism indicators, fat-soluble vitamin content and immune response of animals under seasonal changes have also been described in the literature [21, 37].

For total lipoproteins, multi-vector associations with metabolic and haematological parameters were identified. Significant positive correlations with total calcium ($r = 0.532$; $p = 0.00007$), carotene ($r = 0.399$; $p = 0.0041$), haematocrit ($r = 0.417$; $p = 0.0025$) and Ca/P ratio ($r = 0.294$; $p = 0.0385$) highlight the integrated role of lipid metabolism in the regulation of mineral homeostasis and haematopoiesis. Several authors emphasise that lipoproteins serve as central integrators between the mineral, vitamin and haematopoietic components of adaptation under various models of heat or oxidative stress [38, 52, 53]. Significant negative correlations with AST activity ($r = -0.302$; $p = 0.0329$), MCHC ($r = -0.306$; $p = 0.0303$) and glucose ($r = -0.512$; $p = 0.00014$) reflect complex interactions between lipid, energy and hepatic metabolism. Similar results have been reported in studies with models of summer stress and comparisons of blood lipoprotein and enzyme levels at different times of the year [12, 36].

Trends were also observed for associations with beta-globulins, haemoglobin and platelets, which require further analysis to elucidate their biological significance. At the same time, variability in these parameters has repeatedly been recorded during transitional periods, which may be related to individual animal responses and the impact of seasonal microclimate [22, 43].

Thus, the results obtained indicate that beta-hydroxybutyrate, glucose and lipoproteins are not only biological markers of individual metabolic pathways but also reflect the status of protein, mineral, enzymatic and haematological profiles in a comprehensive manner. The identified significant associations confirm the integration of homeostatic regulatory mechanisms, which is consistent with modern concepts of animal adaptation physiology to climatic and technological factors [8, 54, 55].

Conclusions and prospects for further research. It was established that in Brown Swiss cows kept year-round in a naturally ventilated loose housing system, beta-hydroxybutyrate, glucose and total lipoproteins exhibit close correlations with the main morpho-biochemical blood parameters. These biomarkers were found to be the most sensitive indicators reflecting changes in energy, protein and mineral metabolism, as well as adaptive processes in the animals throughout the year. Further research should focus on assessing the prognostic value of these biomarkers for different dairy cattle breeds, as well as on developing integrated biological indices for systematic monitoring of adaptation and welfare in cattle under industrial conditions with year-round housing in naturally ventilated barns.

References

1. Gao, S. T., Guo, J., Quan, S. Y., Nan, X. M., Fernandez, M. V. S., Baumgard, L. H., & Bu, D. P. (2017). The effects of heat stress on protein metabolism in lactating Holstein cows. *Journal of Dairy Science*, 100(6), 5040–5049. https://doi.org/10.3168/jds.2016-11913
2. Mylostyvyi, R., Lesnovskay, O., Karlova, L., Khmeleva, O., Kalinichenko, O., Orishchuk, O., Tsap, S., Begma, N., Cherniy, N., Gutyj, B., & Izhboldina, O. (2021). Brown Swiss cows are more heat resistant than Holstein cows under hot summer conditions of the continental climate of Ukraine. *Journal of Animal Behaviour and Biometeorology*, 9(4), 1–8. https://doi.org/10.31893/jabb.21034
3. Vasilenko, T., Milostiviy, R., Kalinichenko, A., & Milostiva, D. (2018). Heat stress in dairy cows in the central part of Ukraine and its economic consequences. Social and economic aspects of sustainable development of regions: monograph. Publishing House WSZiA, Opole. URL: https://dspace.dsau.dp.ua/handle/123456789/457
4. Dahl, G. E., Tao, S., & Laporta, J. (2020). Heat Stress Impacts Immune Status in Cows Across the Life Cycle. *Frontiers in Veterinary Science*, 7. https://doi.org/10.3389/fvets.2020.00116
5. Zeng, J., Cai, J., Wang, D., Liu, H., Sun, H., & Liu, J. (2023). Heat stress affects dairy cow health status through blood oxygen availability. *Journal of Animal Science and Biotechnology*, 14(1), 112. https://doi.org/10.1186/s40104-023-00915-3

6. Aggarwal, A., Dar, M. R., Vats, P., Singh, M., Kumar, P., Choudhary, R., & Rawal, V. (2019). Physiological changes and blood flow in different breeds of dairy cows during different seasons. *Biological Rhythm Research*, 52(9), 1322–1333. https://doi.org/10.1080/09291016.2019.1627642
7. Chen, X., Shu, H., Sun, F., Yao, J., & Gu, X. (2023). Impact of Heat Stress on Blood, Production, and Physiological Indicators in Heat-Tolerant and Heat-Sensitive Dairy Cows. *Animals*, 13(16), 2562. https://doi.org/10.3390/ani13162562
8. Mylostyvyi, R. (2025). Impact of acute heat stress on hematological and biochemical profiles in Brown Swiss cows. *Ukrainian Journal of Veterinary and Agricultural Sciences*, 8(1), 8–13. https://doi.org/10.32718/ujvas8-1.02
9. Chabanenko, D. V., & Shynkarenko, R. V. (2025). Seasonal variations in haematological parameters as markers of physiological adaptation in Brown Swiss dairy cows under intensive production. *Scientific Messenger of LNU of Veterinary Medicine and Biotechnologies. Series: Veterinary Sciences*, 27(120), 242-247. https://doi.org/10.32718/nvlvet12029
10. Blond, B., Majkić, M., Spasojević, J., Hristov, S., Radinović, M., Nikolić, S., Anđušić, L., Čukić, A., Došenović Marinković, M., Vujanović, B. D., Obradović, N., & Cincović, M. (2024). Influence of Heat Stress on Body Surface Temperature and Blood Metabolic, Endocrine, and Inflammatory Parameters and Their Correlation in Cows. *Metabolites*, 14(2), 104. https://doi.org/10.3390/metabo14020104
11. Mekroud, M., Arzour-Lakehal, N., Ouchene-Khelifi, N. A., Ouchene, N., Titi, A., & Mekroud, A. (2021). Seasonal variations in hematological profile of Holstein dairy cows as an indicator for physiological status assessment. *Agricultural Science and Technology*, Volume 13, Issue 1, 28–33. https://doi.org/10.15547/ast.2021.01.005
12. Mylostyvyi, R., Sejian, V., Izhboldina, O., Kalinichenko, O., Karlova, L., Lesnovskay, O., Begma, N., Marenkov, O., Lykhach, V., Midyk, S., Cherniy, N., Gutyj, B., & Hoffmann, G. (2021). Changes in the Spectrum of Free Fatty Acids in Blood Serum of Dairy Cows during a Prolonged Summer Heat Wave. *Animals*, 11(12), 3391. DOI: https://doi.org/10.3390/ani11123391
13. Hoffmann, G., Silpa, M. V., Mylostyvyi, R., & Sejian, V. (2021). Non-Invasive Methods to Quantify the Heat Stress Response in Dairy Cattle. Climate Change and Livestock Production: Recent Advances and Future Perspectives, 85–98. https://doi.org/10.1007/978-981-16-9836-1_8
14. Hussein, H. A., Thurmann, J.-P., & Staufenbiel, R. (2020). 24-h variations of blood serum metabolites in high yielding dairy cows and calves. *BMC Veterinary Research*, 16(1). https://doi.org/10.1186/s12917-020-02551-9
15. Rashid, M., Hossain, M., Azad, M., & Hashem, M. (2013). Long term cyclic heat stress influences physiological responses and blood characteristics in indigenous

sheep. *Bangladesh Journal of Animal Science*, 42(2), 96–100. https://doi.org/10.3329/bjas.v42i2.18486

16. Rathwa, S. D., Vasava, A. A., Pathan, M. M., Madhira, S. P., Patel, Y. G., & Pande, A. M. (2017). Effect of season on physiological, biochemical, hormonal, and oxidative stress parameters of indigenous sheep. *Veterinary World*, 10(6), 650–654. https://doi.org/10.14202/vetworld.2017.650-654
17. Tejaswi, V., Bosco, J., Verma, V., Anjali, Pathak, M. C., Samad, H. A., Tiwari, A. K., Chouhan, V. S., Maurya, V. P., Sarkar, M., & Singh, G. (2022). Seasonal alterations in blood biochemical parameters among zebu and crossbred cattle. *Biological Rhythm Research*, 53(12), 1941–1949. https://doi.org/10.1080/09291016.2022.2098619
18. Aleena, J., Sejian, V., Krishnan, G., Bagath, M., Pragna, P., & Bhatta, R. (2020). Heat stress impact on blood biochemical response and plasma aldosterone level in three different indigenous goat breeds. Journal of Animal Behaviour and Biometeorology, 8(4), 266–275. https://doi.org/10.31893/jabb.20034
19. Thammacharoen, S., Semsirmboon, S., Chanpongsang, S., Chaiyabutr, N., Panyasomboonying, P., Khundamrongkul, P., Puchongmart, P., & Wichachai, W. (2021). Seasonal effect of milk yield and blood metabolites in relation to ketosis of dairy cows fed under a high ambient temperature. *Veterinary World*, 2392–2396. https://doi.org/10.14202/vetworld.2021.2392-2396
20. Wang, L., Zhang, P., Du, Y., Wang, C., Zhang, L., Yin, L., Zuo, F., & Huang, W. (2024). Effect of heat stress on blood biochemistry and energy metabolite of the Dazu black goats. *Frontiers in Veterinary Science*, 11. https://doi.org/10.3389/fvets.2024.1338643
21. Nabi, B., Gupta, S. K., Rasool, M., Rasool, S., Najar, A. A., & Umar, S. I. U. (2022). Hemato-biochemical, Antioxidant Alteration in Thermal Stressed Cross-bred Cows and Mitigation using Micronutrients in Sub-tropical Zone of India. *Indian Journal of Animal Research*, 1–9. https://doi.org/10.18805/ijar.b-4846
22. Hadžimusić, N., & Hadžijunuzović-Alagić, D. (2024). Effects of season on metabolic profile of Holstein Friesian cows in postpartum period. *Online Journal of Animal and Feed Research*. LOCKSS. https://doi.org/10.51227/ojafr.2024.34
23. Melendez, P., McDaniel, K., Chacon, C., Poock, S., Bartolome, J., & Pinedo, P. (2020). Association between blood β-hydroxybutyrate at 7 days postpartum and milk yield, disease occurrence and fertility in grazing dairy cattle with seasonal calving: a case study. *Animal Production Science*, 60(14), 1737–1744. https://doi.org/10.1071/an19414
24. Giri, A., Bharti, V. K., Kalia, S., Ravindran, V., Ranjan, P., Kundan, T. R., & Kumar, B. (2017). Seasonal changes in haematological and biochemical profile of dairy cows in high altitude cold desert. *The Indian Journal of Animal Sciences*, 87(6). https://doi.org/10.56093/ijans.v87i6.71080

25. Mylostyvyi, R. V., Wrzecińska, M., Samardžija, M., Gutyj, B. V., Yefimov, V. H., Skliarov, P. M., & Lieshchova, M. O. (2024). Impact of heat stress on blood serum cortisol level in dairy cows. *Theoretical and Applied Veterinary Medicine*, 12(4), 3–8. https://doi.org/10.32819/2024.12016
26. Mylostyvyi, R., Lacetera, N., Amadori, M., Sejian, V., Souza-Junior, J. B. F., & Hoffmann, G. (2023). The autumn low milk yield syndrome in Brown Swiss cows in continental climates: hypotheses and facts. *Veterinary Research Communications*, 48(1), 203–213. https://doi.org/10.1007/s11259-023-10203-0
27. Abbas, Z., Sammad, A., Hu, L., Fang, H., Xu, Q., & Wang, Y. (2020). Glucose Metabolism and Dynamics of Facilitative Glucose Transporters (GLUTs) under the Influence of Heat Stress in Dairy Cattle. *Metabolites*, 10(8), 312. https://doi.org/10.3390/metabo10080312
28. Lora, I., Calderone, C., Prussiani, L., Contiero, B., Malagoli, S., Lotto, A., & Cozzi, G. (2024). Reference limits for blood gas analysis performed from coccygeal vessels of multiparous Holstein dairy cows: Effects of stage of lactation and season of sampling. *Journal of Dairy Science*, 107(11), 9839–9846. https://doi.org/10.3168/jds.2024-24859
29. Kim, W.-S., Nejad, J. G., Park, K.-K., & Lee, H.-G. (2023). Heat Stress Effects on Physiological and Blood Parameters, and Behavior in Early Fattening Stage of Beef Steers. *Animals*, 13(7), 1130. https://doi.org/10.3390/ani13071130
30. Sukandi, S., Rahardja, D. P., Sonjaya, H., Hasbi, H., Baco, S., Gustina, S., & Adiputra, K. D. D. (2023). Effect of Heat Stress on the Physiological and Hematological Profiles of Horned and Polled Bali Cattle. *Advances in Animal and Veterinary Sciences*, 11(6). https://doi.org/10.17582/journal.aavs/2023/11.6.893.902
31. Syafiqa, N. N., Zulkifli, I., Zuki, A. B. Md., Meng Goh, Y., & Kaka, U. (2023). Physiological, haematological and electroencephalographic responses to heat stress in Katjang and Boer goats. *Saudi Journal of Biological Sciences*, 30(11), 103836. https://doi.org/10.1016/j.sjbs.2023.103836
32. Santos, F. C. R. dos, Santarosa, B. P., Dal Más, F. E., Silva, K. N. da, Guirro, É. C. B. do P., & Gomes, V. (2024). Effects of dam metabolic profile and seasonality (Spring vs. Winter) on their offspring' metabolism, health, and immunity: maternal factors in dairy calves' analytes. *Frontiers in Veterinary Science*, 11. https://doi.org/10.3389/fvets.2024.1424960
33. Pawliński, B., Gołębiewski, M., Trela, M., & Witkowska-Piłaszewicz, O. (2023). Comparison of blood gas parameters, ions, and glucose concentration in polish Holstein-Friesian Dairy cows at different milk production levels. *Scientific Reports*, 13(1). https://doi.org/10.1038/s41598-023-28644-7
34. Mylostyva, D., Prudnikov, V., Kolisnyk, O., Lykhach, A., Begma, N., Kalinichenko, O., Khmeleva, O., Sanzhara, R., Izhboldina, O., & Mylostyvyi, R. (2022).

Biochemical changes during heat stress in productive animals with an emphasis on the antioxidant defense system. *Journal of Animal Behaviour and Biometeorology*, 10(1), 1–9. https://doi.org/10.31893/jabb.22009

35. Baccouri, W., Wanjala, G., Tóth, V., Komlósi, I., Földesi, I., Diána, K., & Mikó, E. (2025). The effect of seasonal changing temperature on blood metabolic indicators in Holstein Friesian cows. *Cogent Food & Agriculture*, 11(1). https://doi.org/10.1080/23311932.2025.2550498
36. Joo, S. S., Lee, S. J., Park, D. S., Kim, D. H., Gu, B.-H., Park, Y. J., Rim, C. Y., Kim, M., & Kim, E. T. (2021). Changes in Blood Metabolites and Immune Cells in Holstein and Jersey Dairy Cows by Heat Stress. *Animals*, 11(4), 974. https://doi.org/10.3390/ani11040974
37. Mary, A. E. P., Artavia Mora, J. I., Ronda Borzone, P. A., Richards, S. E., & Kies, A. K. (2021). Vitamin E and beta-carotene status of dairy cows: a survey of plasma levels and supplementation practices. *Animal*, 15(8), 100303. https://doi.org/10.1016/j.animal.2021.100303
38. Bahrami-Yekdangi, M., Ghorbani, G. R., Sadeghi-Sefidmazgi, A., Mahnani, A., Drackley, J. K., & Ghaffari, M. H. (2022). Identification of cow-level risk factors and associations of selected blood macro-minerals at parturition with dystocia and stillbirth in Holstein dairy cows. *Scientific Reports*, 12(1). https://doi.org/10.1038/s41598-022-09928-w
39. Kozyr, V. S., Antonenko, P. P., Mylostyvyi, R. V., Suslova, N. I., Skliarov, P. M., Reshetnychenko, O. P., Pushkar, T. D., Sapronova, V. O., & Pokhyl, O. M. (2019). Effect of herbal feed additives on the quality of colostrum, immunological indicators of newborn calves blood and growth energy of young animals. *Theoretical and Applied Veterinary Medicine*, 7(3), 137–142. https://doi.org/10.32819/2019.71024
40. Farafonov, S., Yaremko, O., Verkholiuk, M., Muzyka, L., Gutyj, B., Marenkov, O., Lykhach, V., Nemova, T., Khmelova, O., & Mylostyvyi, R. (2024). Determining Trace Elements in the Hair of Beef Cattle as a Non-Invasive Method for Assessing Mineral Metabolism. *Journal of Animal Health and Production*, 12(s1). https://doi.org/10.17582/journal.jahp/2024/12.s1.332.337
41. Gutyj, B. V., Goralskyi, L. P., Mylostyvyi, R. V., Sokulskyi, I. M., Stadnytska, O. I., Vus, U. M., Khariv, I. I., Martyshuk, T. V., Leskiv, Kh. Ya., Vozna, O. Ye., Adamiv, S. S., & Petrychka, V. V. (2024). The influence of "Butaselmevit" on the antioxidant status of the cows' organisms during the development of endotoxicosis. *Scientific Messenger of LNU of Veterinary Medicine and Biotechnologies*, 26(114), 210–216. https://doi.org/10.32718/nvlvet11431
42. Hu, L., Brito, L. F., Luo, H., Chen, S., Johnson, J. S., Sammad, A., Guo, G., Xu, Q., & Wang, Y. (2023). Differential Responses of Physiological Parameters, Production Traits, and Blood Metabolic Profiling between First- and Second-Parity Holstein

Cows in the Comparison of Spring versus Summer Seasons. *Journal of Agricultural and Food Chemistry*, 71(31), 11902–11920. https://doi.org/10.1021/acs.jafc.3c00043

43. Chabanenko, D. V., & Shynkarenko, R. V. (2025). Biochemical indicators of adaptation and stress across seasons in Brown Swiss dairy cows. Ukrainian Journal of Veterinary and Agricultural Sciences, 8(3), 79–83. https://doi.org/10.32718/ujvas8-3.10
44. Zachut, M., Kra, G., Nemes-Navon, N., Ben-Aharon, N., Moallem, U., Lavon, Y., & Jacoby, S. (2020). Seasonal heat load is more potent than the degree of body weight loss in dysregulating immune function by reducing white blood cell populations and increasing inflammation in Holstein dairy cows. *Journal of Dairy Science*, 103(11), 10809–10822. https://doi.org/10.3168/jds.2020-18547
45. Mylostyvyi, R., & Izhboldina, O. (2025). An Integrated Approach Using Temperature–Humidity Index, Productivity, and Welfare Indicators for Herd-Level Heat Stress Assessment in Dairy Cows. *Animals*, 15(22), 3341. https://doi.org/10.3390/ani15223341
46. Antonenko, P. P., Dorovskych, A. V., Vysokos, M. P., Mylostyvyi, R. V., Kalinichenko, O. O., & Vasilenko, T. O. (2018). Methodological bases and methods of scientific research in veterinary hygiene, sanitary and expertise. Dnipro, "Svidler A.L."
47. Kaneko, J. J., Harvey, J. W., & Bruss, M. L. (Eds.). (2008). Clinical Biochemistry of Domestic Animals (6th ed.). Academic Press. https://doi.org/10.1016/B978-0-12-370491-7.X0001-3
48. O'Brien, M. D., Rhoads, R. P., Sanders, S. R., Duff, G. C., & Baumgard, L. H. (2010). Metabolic adaptations to heat stress in growing cattle. *Domestic Animal Endocrinology*, 38(2), 86–94. https://doi.org/10.1016/j.domaniend.2009.08.005
49. Belhadj Slimen, I., Najar, T., Ghram, A., & Abdrrabba, M. (2015). Heat stress effects on livestock: molecular, cellular and metabolic aspects, a review. *Journal of Animal Physiology and Animal Nutrition*, 100(3), 401–412. https://doi.org/10.1111/jpn.12379
50. Duda, Y. V., Prus, M. P., & Shevchik, R. S. (2020). Seasonal influence on biochemical blood parameters in males of Californian rabbit breed. *Ukrainian Journal of Ecology*, 10 (4), 262–268. https://doi.org/10.15421/2020_197
51. Mylostyvyi, R. (2025). The effect of prolonged heat stress on haematological parameters of Holstein cows. *Ukrainian Journal of Veterinary Sciences*, 16(1), 59–69. https://doi.org/10.31548/veterinary1.2025.59
52. Sklyarov, P., Fedorenko, S., & Naumenko, S. (2020). Oxidant/Antioxidant Balance in Cows and Sheep in Antenatal Pathology. *Ukrainian Journal of Ecology*, 10(5), 26–28. https://doi.org/10.15421/2020_201

53. Valencia, R., Kim, S. H., Berdos, J., Kim, M. H., Lee, S. S., & Lee, S. S. (2024). Metabolic and Metataxonomic Changes in Lactating Holstein Dairy Cows During the Transition from Heat Stress to the Recovery Period. *Journal of Animal Science and Technology*. https://doi.org/10.5187/jast.2024.e97
54. Važić, B., Drinić, M., Kasagić, D., Popadić, S., & Rogić, B. (2020). Metabolic profile of the blood of Simmental cows during a production cycle. *Veterinarski Arhiv*, 90(1), 11–18. https://doi.org/10.24099/vet.arhiv.0371
55. Alrhmoun, M., Gauly, M., & Poulopoulou, I. (2025). Seasonal prevalence and geographical distribution of claw health in dairy cows: Investigation of the causal relationship with breed. *Journal of Dairy Science*, 108(1), 980–995. https://doi.org/10.3168/jds.2024-25204

Дмитро Чабаненко,
аспірант, Дніпровський державний аграрно-економічний
університет, м. Дніпро, Україна
ORCID ID: 0009-0000-1898-5010
e-mail: 11590948@student.dsau.dp.ua

Роман Шинкаренко,
аспірант, Дніпровський державний аграрно-економічний
університет, м. Дніпро, Україна
ORCID ID: 0009-0003-3819-6539
e-mail: 12286177@student.dsau.dp.ua

КОРЕЛЯЦІЯ МІЖ КЛЮЧОВИМИ БІОМАРКЕРАМИ (БЕТА-ГІДРОКСИБУТИРАТ, ГЛЮКОЗА, ЛІПОПРОТЕЇДИ) ТА ПОКАЗНИКАМИ КРОВІ У ШВІЦЬКИХ КОРІВ ЗА УТРИМАННЯ У ПРИРОДНО ВЕНТИЛЬОВАНОМУ ПРИМІЩЕННІ

Анотація

У роботі досліджено особливості взаємозв'язків між ключовими біомаркерами енергетичного та ліпідного обміну (бета-гідроксибутират, глюкоза, ліпопротеїди) і морфо-біохімічними показниками крові у корів бурої швіцької породи за умов цілорічного утримання у природно-вентильованому приміщенні. Актуальність проблеми зумовлена зростанням частоти метаболічних порушень і прояву теплового стресу у високопродуктивних тварин, що посилюється за впливу сезонних коливань мікроклімату. Вивчення інформативності кров'яних біомаркерів є перспективним для ранньої діагностики метаболічного напруження та підвищення ефективності контролю за станом добробуту тварин. Дослідження проведено на коровах другої лактації ($n=50$) на одному з найбільших молочних комплексів із розведення бурої швіцької породи в центральній частині України. За кожним сезоном року випадковим чином були сформовані репрезентативні групи молочних корів з однаковою продуктивністю і періодом лактації. Досліджували білковий, ліпідний, вуглеводний і мінеральний обмін, а також показники кровотворення. Погодні умови (температура, вологість, розрахунок температурно-вологісного індексу) оцінювали за даними найближчої метеостанції. Взаємозв'язок між показниками крові визначали за коефіцієнтом кореляції Спірмена. Представлення даних і статистична обробка проведені із використанням програмного забезпечення Statistica 12 (StatSoft Inc., USA). Достовірними вважали результати при $P \leq 0,05$. Результати показали, що бета-гідроксибутират мав достовірні негативні зв'язки з активністю печінкових ферментів (АЛТ, $r = -0,465$; АСТ, $r = -0,321$; $p < 0,05$). Глюкоза негативно корелювала із загальним кальцієм ($r = -0,742$; $p < 0,05$), співвідношенням Ca/P ($r = -0,561$; $p < 0,05$), гематокритом ($r = -0,472$; $p < 0,05$), загальними ліпопротеїдами ($r = -0,512$; $p < 0,05$) та альбумінами ($r = -0,283$; $p < 0,05$), а позитивно – з неорганічним фосфором ($r = 0,309$; $p < 0,05$), МСН ($r = 0,333$; $p < 0,05$) і МСНС ($r = 0,385$; $p < 0,05$). Для ліпопротеїдів виявився характерним позитивний зв'язок із загальним кальцієм ($r = 0,532$; $p < 0,05$), каротином ($r = 0,399$; $p < 0,05$), гематокритом ($r = 0,417$; $p < 0,05$), Ca/P ($r = 0,294$; $p < 0,05$) та негативний – з АСТ ($r = -0,302$; $p < 0,05$) та МСНС ($r = -0,306$; $p < 0,05$). Виявлені достовірні кореляції між ключовими біомаркерами і гематологічними показниками відображають комплексність регуляторних механізмів гомеостазу. Отримані дані підтверджують доцільність одночасного моніторингу бета-гідроксибутират, глюкоза, ліпопротеїди в крові для оцінки метаболічної адаптації та ризиків розвитку порушень за сучасних систем утримання молочних корів.

***Ключові слова**: корови швіцької породи, біомаркери, морфологічні і біохімічні показники крові, кореляція, адаптація, мікроклімат.*

Стаття надійшла до редакції 20 січня 2026 року
Стаття пройшла рецензування 23 лютого 2026 року
Стаття опублікована 30 березня 2026 року.