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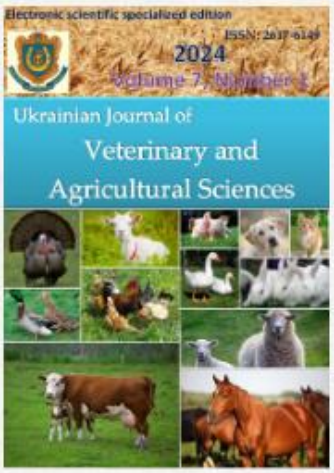

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Adaptive changes in immunological, hematological and metabolic profiles of pregnant cows

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Abstract

Pregnancy triggers a series of complex interactions within the body, involving both the immune system and metabolic processes. In the case of pregnant cows, these mechanisms are essential for supporting the developing fetus and maintaining the overall health of the mother. The aim of the work was to study the hematological, biochemical, and immunological parameters of cows at different periods of pregnancy. Research was conducted on cows (*Bos Taurus*) of the *Ukrainian Black-and-White dairy breed*. Groups were formed based on the principle of analogs. The research was carried out using the methodology of group-period experiments. The control group consisted of non-pregnant cows. The first observation period was conducted on pregnant cows with confirmed pregnancy (30 days). The second observation period was carried out at 90 days of pregnancy, the third at 180 days of gestation, and the fourth at 270 days. Laboratory studies included immunological research conducted in the specialized laboratory of immunology for reproduction animals. The first notable observation was the gradual increase in the population of CD^{3+} lymphocytes from the beginning of gestation, which remained stable until the 90th day of pregnancy and then gradually decreased. The population of B cell immune cells CD^{22+} had its peculiarities: dynamic and stable growth from the start of pregnancy until the middle of the second trimester (180 days), followed by a gradual decrease until the onset of labor. The redistribution of T and B lymphocytes occurred with dynamic fluctuations in the number of undifferentiated 0-lymphocytes. The processes of transformation and adaptation of homeostasis affected both enzyme activity and indicators of mineral metabolism. Thus, from the beginning of pregnancy (from the 30th day of gestation), the experimental cows showed a significant increase in alkaline phosphatase activity ($P < 0.05$), alanine aminotransferase ($P < 0.05$), and aspartate aminotransferase activity ($P < 0.05$). During the pregnancy of cows, body changes occur. From the early period of gestation throughout the entire period of embryogenesis, changes in the system of hematopoiesis, alterations in the activity of enzymes, exchange of Ca and P, accompanied by changes in immunological reactions take place. These processes are adaptive and ensure the maintenance of the homeostasis system. The perspective of further research will aim at studying changes in immunological and biochemical parameters during physiological pregnancy and when it is complicated.

Keywords: cows; pregnancy; immune system; hematology; biochemistry parameters.

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1. Introduction

The immune system plays a crucial role in ensuring the success of pregnancy in animals, including cows (Alhussien et al., 2018; Mohapatra et al., 2020; Mojsym et al., 2022). Pregnancy triggers a series of complex interactions within the body, involving both the immune system and metabolic processes. In the case of pregnant cows, these mechanisms are essential for supporting the developing fetus and maintaining the overall health of the mother (Kamat et al., 2016; Sheikh et al., 2018; Zhelavskyi et al., 2022).

Firstly, the immune system plays a pivotal role in preventing the rejection of the developing fetus. During pregnancy, the mother's immune system must tolerate the presence of the semi-allogenic fetus, which contains paternal antigens that differ from the mother's own (Ott et al., 2019; Mohammed et al., 2022). This tolerance is facilitated by various immunological adaptations, including the suppression of certain immune responses that might otherwise recognize the fetus as foreign and mount an attack. This immune tolerance is crucial for a successful pregnancy and the prevention of miscarriage (Talukder et al., 2018; Leppo et al., 2021; Rutigliano et al., 2022).

Additionally, the immune system helps protect both the mother and the developing fetus from infections. Pregnancy is a vulnerable period, as the mother's body undergoes changes that may compromise her immune defenses. A balanced immune response is necessary to fend off potential pathogens without triggering harmful inflammation that could negatively impact the pregnancy (Talukder et al.,

2018; Fiorenza et al., 2021). The immune system's ability to regulate inflammation becomes particularly important during this period (Alhussien & Dang, 2019; Fiorenza et al., 2021; Zhelavskyi et al., 2021).

Moreover, metabolic processes undergo significant changes in pregnant cows to meet the nutritional demands of the developing fetus. As the pregnancy progresses, the cow's body adapts to the increased metabolic requirements, directing nutrients toward the developing fetus. Hormones, such as progesterone and estrogen, play a key role in orchestrating these metabolic changes. The immune system interacts with these hormonal changes to ensure a harmonious balance between the demands of pregnancy and the overall health of the cow (Manjari et al., 2016; Fávero et al., 2018).

The placenta, a vital organ during pregnancy, also contributes to the intricate interplay between the immune system and metabolic processes. It serves as a barrier that protects the fetus from potential pathogens while facilitating the exchange of nutrients and waste products between the mother and the developing offspring. The immune system actively participates in maintaining the integrity of the placental barrier and responding to any potential threats that may arise (Zhelavskyi et al., 2020; Czyżewska-Dors et al., 2022).

Thus, immune system is indispensable in ensuring the success of pregnancy in animals, including cows. Its role extends beyond preventing rejection and protecting against infections to actively participating in the complex interplay of metabolic processes associated with gestation. Understanding these intricate mechanisms is essential for ensuring the health and well-being of both the mother and the developing fetus throughout the pregnancy journey (Kowalczyk et al., 2021; Rocha et al., 2021).

From the beginning of pregnancy, adaptive changes occur in the mother's body. Hormonal regulation changes and necessary conditions are created for implantation, trophic growth, and development of the embryo (Talukder et al., 2018; Fiorenza et al., 2021).

At all stages of pregnancy, changes occur in the mother's body aimed at maintaining homeostasis parameters. Metabolic processes during pregnancy are often on the verge of "breakdown", which leads to the development of several diseases (Ferreira et al., 2021; Goldansaz et al., 2022). It is known that pregnancy is accompanied by a change in the state of the immune system aimed at preserving the fetus. Various theories have been proposed to explain the immune mechanisms for pregnancy maintenance.

For a long time, views on pregnancy as a state of immunosuppression or even immunodeficiency were widespread in scientific circles. Moreover, important changes in the mammalian immune system during pregnancy remain largely unexplored (Gomaa et al., 2021).

Research in recent years has shown that natural immunity is the basis for protecting the body against infections. Understanding of the role of natural factors in immune protection has made it possible to define approaches to the prevention and treatment of bacterial, viral, and autoimmune diseases (Sheikh et al., 2018; Zhelavskyi et al., 2023). Accordingly, approaches to defining the "immunological paradox" of pregnancy have changed.

One of the reasons for the development of preeclampsia in cows is metabolic and immunological changes. Scientists and practitioners need to study physiological adaptations during pregnancy. This is based on the determination of dynamic changes in hematological, immunological, and biochemical parameters. The shift in constants has important diagnostic and prognostic value in veterinary practice (Velázquez et al., 2019; Zhelavskyi et al., 2023).

The *aim* of the work was the study of the hematological, biochemical, and immunological parameters of cows at different periods of pregnancy.

2. Materials and methods

Ethical approval. This investigation was approved according to the Law of Ukraine "On the Protection of Animals from Cruel Treatment" (No. 3447-IV of February 21, 2006) and according to the requirements of the European Convention for the Protection of Pet Animals (ETS No. 125, Strasbourg, 13/11/1987). All experiments were carried out with the Ethical Permit at the Vinnytsia National Agrarian University, Ukraine. All animal manipulations were performed by the European Convention for the Protection of Vertebrate Animals and used for experimental and scientific purposes (Strasbourg, 18 March 1986).

Experimental studies. Researched were conducted on cows *(Bos Taurus)* of the *Ukrainian Black-and-White dairy breed*. Groups were formed based on the principle of analogs. The research was carried out using the methodology of group-period experiments (2019–2024).

The control group consisted of non-pregnant cows (n = 17). The first observation period was conducted on pregnant cows (n = 17) with confirmed pregnancy (30 days). The second observation period was carried out at 90 days of pregnancy, the third at 180 days of gestation, and the fourth at 270 days.

All animals were clinically healthy and handled carefully to prevent any possible effects of stress on the parameters analyzed. They were routinely vaccinated and treated with anthelmintics twice a year. Before morning feeding, blood samples were taken from the animals between 8:00 a.m. and 9:00 a.m. Blood was taken from the *v.jugulares* into evacuated glass containers.

Laboratory studies. Immunological studies were conducted in the specialized laboratory of immunology reproduction animals at Podolian State University, founded by Dr. V.A. Yablonskyi, a Doctor of Biological Sciences and Professor. In the immunological testing of the first level, the total number of leukocytes ($\times 10^9$/L, %), leukogram (%), populations of immunocompetent cells (CD^{3+}, $\times 10^{12}$/L, %; CD^{22+}, $\times 10^{12}$/L, %) were determined.

Hematological research determined the total number of erythrocytes ($\times 10^{12}$/L), the content of hemoglobin (μmol/L), hematocrit (L/L), mean corpuscular volume (MCV, fl); mean corpuscular hemoglobin (MCH, fmol); mean corpuscular hemoglobin concentration (MCHC, mmol/L). To determine these parameters, the Abaxis Vetscan HM5 Hematology Analyzer (USA) was used in the laboratory immunology of reproduction animals.

Biochemical research determined the concentration of alkaline phosphatase activity (AP, mmol/L), alanine aminotransferase activity (ALT, mmol/L), aspartate aminotransferase activity (AST, mmol/L), concentration of Ca^{2+} (mmol/L), P (mmol/L). For biochemical research, the ABAXIS Vetscan VS2 Chemistry Analyzer 2 Gen Version 3.1.33 (USA) was used.

Statistical analysis. The values in this investigation are presented as mean ± SD. The data in this investigation are given as the mean ± SD. Data were analyzed by one-way

analysis of variance (MANOVA). Differences were considered statistically significant at a P-value of less than 0.05 (Statistica® 12.6, StatSoft, USA).

3. Results and discussion

3.1 Results

From the onset of gestation and throughout the second and third trimesters of pregnancy, dynamic changes occurred in the blood of cows. These changes in the peripheral bloodstream encompassed both the morphological composition of cells and their population structure. The indicators of erythrocytes exhibited specific characteristics by absolute values. At the beginning of the first trimester (30th day) of pregnancy, the erythrocyte count was (7.21 ± 0.04×10^{12}/L), showing a tendency to increase and gradually decrease during the dry period (Table 1). Parameters such as hemoglobin concentration, hematocrit, mean corpuscular hemoglobin concentration, mean corpuscular hemoglobin, and mean corpuscular hemoglobin concentration underwent dynamic changes.

Table 1
Hematological parameters cows in different periods of pregnant (M ± m)

Parameter	Units	Control	30 day	90 day	180 day	270 day
Erythrocytes	×10^{12}/L	7.21 ± 0.34	7.62 ± 0.23	8.24 ± 0.12*	8.41 ± 0.18*	8.23 ± 0.12*
Leukocytes	×10^{9}/L	10.51 ± 0.32	12.14 ± 0.21**	11.05 ± 0.24*	11.27 ± 0.45*	11.61 ± 0.24*
Neutrophil	%	44.15 ± 1.32	49.21 ± 1.21*	45.21 ± 1.24	53.72 ± 1.24**	49.38 ± 1.45**
Lymphocyte	%	49.85 ± 1.12	45.54 ± 2.01*	53.43 ± 1.54**	38.21 ± 1.23**	36.01 ± 1.17**
Eosinophils	%	3.03 ± 0.02	3.24 ± 0.08	4.78 ± 0.10*	3.05 ± 0.04	5.21 ± 0.04**
Monocytes	%	2.97 ± 0.24	2.01 ± 0.24	3.42 ± 0.34*	5.02 ± 0.17**	9.40 ± 0.12*
Basophils	%	0	0	0	0	0
Hemoglobin	µmol/L	1117.22 ± 12.14	1121.12 ± 9.17	1135.14 ± 8.17*	1256.34 ± 11.22**	1454.9 ± 9.21**
Haematocrit	L/L	0.31 ± 0.02	0.34 ± 0.05*	0.35 ± 0.07*	0.37 ± 0.04**	0.39 ± 0.08**
MCV	fl	36.21 ± 1.35	37.17 ± 1.14*	39.45 ± 1.12**	41.22 ± 1.71**	44.51 ± 1.21**
MCH	fmol	0.93 ± 0.04	0.73 ± 0.03**	0.74 ± 0.02**	0.89 ± 0.08*	1.15 ± 0.07**
MCHC	mmol/L	33.89 ± 1.12	32.72 ± 1.15*	31.21 ± 1.83*	34.17 ± 1.52*	38.01 ± 1.21**

Note: MCV – mean corpuscular volume; MCH – mean corpuscular hemoglobin; MCHC – mean corpuscular hemoglobin concentration; *P ≤ 0.05; **P ≤ 0.01 as compared with the control group

Pregnancy was also accompanied by alterations in leukopoiesis and the redistribution of leukocytes in the peripheral bloodstream of the experimental cows. Initially, we observed a slight increase in the number of leukocytes at the beginning of embryo implantation, which subsequently did not undergo significant fluctuations.

Such dynamic changes primarily occurred due to the quantity and redistribution of neutrophils and lymphocytes. In contrast, the number of monocytes gradually tended to increase throughout all observation periods, remaining within the physiological ranges of homeostasis.

The quantitative indicators of eosinophils in the initial periods of pregnancy showed non-significant fluctuations. However, at the beginning of the dry period, the content of these microphages gradually increased.

We also observed changes in the functioning of adaptive immunity in cows. The cellular and humoral defense of specific immunity in pregnant animals underwent certain adaptive processes.

The first notable observation was the gradual increase in the population of CD^{3+} lymphocytes from the beginning of gestation, which remained stable until the 90th day of pregnancy and then gradually decreased.

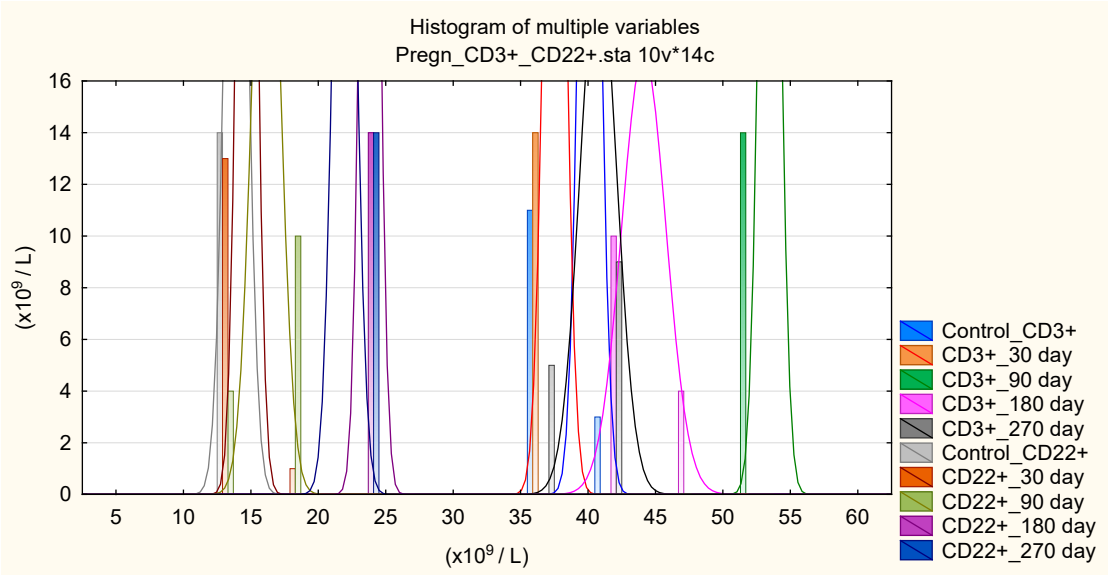

Fig. 1. Dynamics of lymphocytes (CD^{3+}, CD^{22+}) in different periods of cow pregnancy

The population of B cell immune cells CD^{22+} had its peculiarities: dynamic and stable growth from the start of pregnancy until the middle of the second trimester (180 days), followed by a gradual decrease until the onset of labor. The redistribution of T and B lymphocytes occurred with dynamic fluctuations in the number of undifferentiated 0-lymphocytes (Figure 1).

Pregnancy in cows was also accompanied by changes in biochemical parameters. The processes of transformation and adaptation of homeostasis affected both enzyme activity and indicators of mineral metabolism. Thus, from the beginning of pregnancy (from the 30th day of gestation), the experimental cows showed a significant increase in alkaline phosphatase activity ($P < 0.05$), alanine aminotransferase ($P < 0.05$), and aspartate aminotransferase activity ($P < 0.05$).

Subsequently, the values of AP and ALT stabilized and slightly decreased until the end of pregnancy. AST activity during the dry period and the transition to lactation showed minor activation (Figure 2).

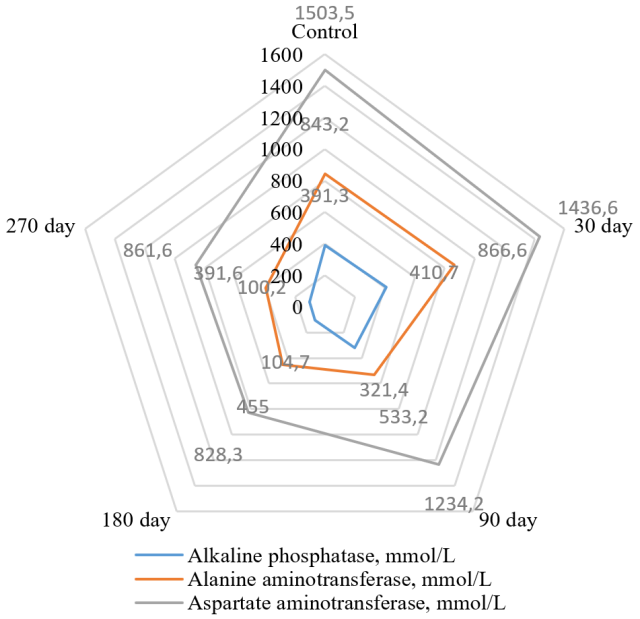

Fig. 2. Change in the activity of enzymes (AP, ALT, AST) in the body of cows during pregnancy

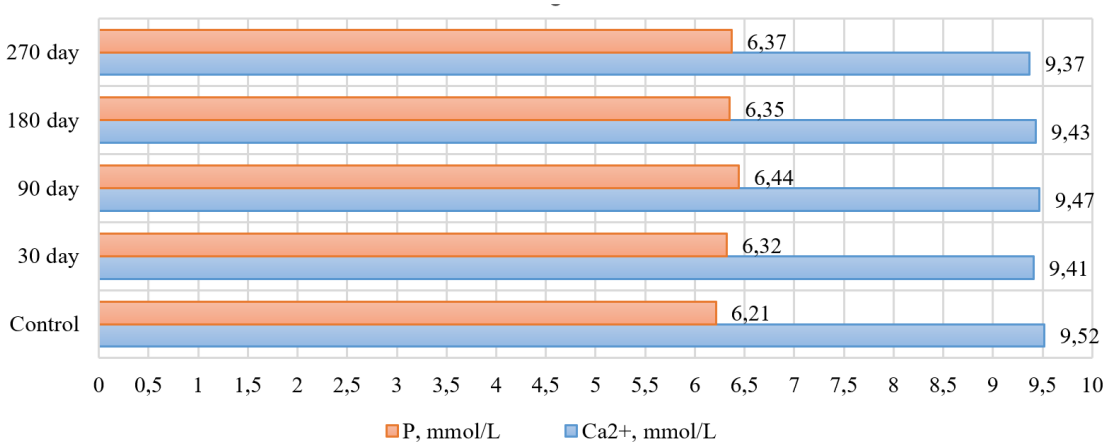

Fig. 3. Changes in the concentration of Calcium (Ca^{2+}) and Phosphorus (P) in the body of cows in different periods of pregnancy

Interesting results were obtained in the mineral metabolism indicators. The Calcium (Ca^{2+}) content in the cows' blood gradually decreased from the beginning to the end of pregnancy ($P < 0.05$). The concentration of Phosphorus reached its maximum value on the 90th day (Figure 3) of observation (6.44 ± 0.01 mmol/L) and gradually decreased with the development of embryogenesis.

3.2 Discussion

During pregnancy, cows undergo significant physiological changes to support the developing fetus and prepare for lactation. Monitoring biochemical indicators in the blood of cows throughout various stages of pregnancy can provide valuable insights into their health status and reproductive performance. Some essential biochemical indicators that are commonly assessed during different periods of cow pregnancy (Alhussien et al., 2018; Rutigliano et al., 2022).

In this study, we studied the functioning of the adaptive immunity of cows during pregnancy, investigated the state of the blood system and metabolic processes.

Research into the distinct roles of the endocrine and immune systems in reproductive biology and their impact on fertility remains ongoing and not entirely conclusive (Walsh et al., 2011). Some earlier studies indicated that treating cows with estradiol-17β or progesterone post-ovariectomy did not significantly affect changes in uterine polymorphonuclear leukocyte functions. However, estradiol-17β treatment during estrus did result in enhanced polymorphonuclear leukocyte functions. Similarly, progesterone plays a critical role in fertility, particularly in establishing and maintaining pregnancy. Studies with beef heifers and dairy cows have shown positive connections between higher concentrations of progesterone and improved immune functions immediately after conception (Velázquez et al., 2019; Zhelavskyi et al., 2020; Leppo et al., 2022).

These findings suggest that the endometrium in cattle undergoes remodeling throughout the estrous cycle, with significant changes in signaling molecules affecting immune processes and regulation (Mohammed et al., 2022). Endometrial luminal epithelial cells actively contribute to the immune response by producing pro-inflammatory factors

like cytokines and chemokines. The endometrial tissues possess both local innate and adaptive response mechanisms, varying with the hormonal status during different reproductive phases (Zhelavskyi, 2021; Rutigliano et al., 2022).

The uterine immune system in cows serves crucial roles during gestation, supporting pregnancy and fetal growth while preventing infections. However, both before and after calving, when significant hormonal and metabolic changes occur, the immune status can be severely affected. For instance, there's a notable surge in cortisol concentrations during calving, leading to leukocytosis, and this period is associated with higher susceptibility to diseases (Ott, 2019; Zhelavskyi & Dmytriv, 2023).

The determination of prognostic biochemical markers of pregnancy is important in veterinary practice (Goldansaz et al., 2022). The prognostic of biochemical markers of pregnancy holds significant importance in veterinary practice, contributing to the overall health and reproductive success of animals. Veterinary professionals employ a range of biochemical markers to assess and monitor the progression of pregnancy in different species, aiding in timely interventions, if necessary.

One crucial aspect of utilizing prognostic biochemical markers is the early detection of pregnancy. In many cases, identifying pregnancy at an early stage is essential for implementing appropriate management practices, and nutritional adjustments, and ensuring the well-being of both the dam and the developing fetus. Biochemical markers such as pregnancy-associated glycoproteins, progesterone, and estradiol play pivotal roles in confirming and monitoring pregnancy status (Tufarelli et al., 2023).

Pregnancy-associated glycoproteins, produced by the placenta, are widely recognized as reliable indicators of pregnancy in ruminants. Monitoring the concentrations of PAGs in the blood allows veterinarians to confirm the presence of a viable pregnancy and estimate the gestational age. This information is vital for managing reproductive calendars and optimizing breeding programs. Progesterone, another crucial biochemical marker, is fundamental for the establishment and maintenance of pregnancy. Monitoring progesterone levels helps assess the functional status of the corpus luteum, a temporary endocrine structure critical for early pregnancy. In cases of luteal insufficiency or early embryonic mortality, alterations in progesterone levels can serve as early indicators, prompting necessary interventions. Estradiol, a form of estrogen, is significant in various reproductive processes, including fetal development and parturition. Monitoring estradiol levels aids in understanding the hormonal dynamics during pregnancy and can be indicative of the well-being of the developing fetus (Molefe & Mwanza, 2020).

Additionally, assessing markers like blood urea nitrogen, glucose, and calcium is essential for evaluating the nutritional status and metabolic health of pregnant animals. Imbalances in these markers may signify nutritional deficiencies or metabolic disorders that can impact the overall health of both the dam and the offspring (Ferreira et al., 2021).

Regular monitoring of these prognostic biochemical markers enables veterinarians to detect potential complications early on, facilitating timely interventions and enhancing the chances of a successful pregnancy outcome. This proactive approach contributes to improved reproductive management, increased fertility rates, and better overall animal welfare.

Important changes in the body of cows occur in the body of cows during the transistor period (Ferreira et al., 2021; Perry et al., 2021).

A primary goal of dairy herd management is to maximize milk production while maintaining optimal reproduction efficiency. Reproduction significantly impacts the profitability of dairy cattle breeding as it influences milk production continuity and calving intervals (Gomaa et al., 2021; Noori Sabzikar et al., 2023).

Metabolic disorders and immune changes during cow pregnancy are critical aspects influencing the health and reproductive success of dairy and beef cattle. The physiological demands of pregnancy trigger significant metabolic shifts to support fetal development, resulting in alterations in nutrient metabolism and immune function (Kaiser et al., 2022; Zhelavskyi et al., 2023).

During pregnancy, cows experience metabolic adaptations characterized by changes in nutrient utilization, hormonal profiles, and energy expenditure. Metabolic disorders such as ketosis, a common concern in dairy cows, may arise due to an imbalance between energy intake and expenditure. Ketosis negatively impacts the cow's overall health and immune response, making them more susceptible to infections (Velázquez et al., 2019; Goldansaz et al., 2022).

The immune system undergoes dynamic changes throughout pregnancy to accommodate the developing fetus. The maternal immune system must strike a delicate balance to protect against pathogens while tolerating the semi-allogeneic fetus. Immune suppression during certain phases of pregnancy, especially around parturition, can increase the risk of diseases (Ferreira et al., 2021).

Key biochemical markers, such as acute-phase proteins and cytokines, play crucial roles in assessing metabolic and immune status during pregnancy. Monitoring these markers allows veterinarians to detect metabolic disorders early and evaluate the cow's immune response. For instance, increased concentrations of acute-phase proteins may indicate inflammation or infection, signaling a compromised immune system (Velázquez et al., 2019).

Addressing metabolic disorders and immune changes during pregnancy requires a comprehensive approach. Nutritional management plays a pivotal role in preventing metabolic disorders, ensuring adequate energy and nutrient intake to support both the cow and the developing fetus. Additionally, proper vaccination protocols and hygiene practices are essential to prevent infections that could exploit the immune vulnerabilities associated with pregnancy (Ott, 2019).

Understanding the intricate interplay between metabolic adaptations and immune dynamics during cow pregnancy is crucial for maintaining herd health and optimizing reproductive performance. Veterinary interventions focused on early detection, nutritional support, and preventive measures contribute to the overall well-being of pregnant cows, leading to successful pregnancies, healthier offspring, and improved farm productivity.

Dairy cattle are commonly diagnosed and assessed for health status by examining their hematological profiles. This analysis helps detect productive and reproductive disorders, identifying changes in biomarkers linked to factors such as disease, pregnancy, or stress. The hematological profile of cows varies based on climate, season, age, body condition, and nutrition. Notably, changes in blood parameters occur during pregnancy and lactation due to increased demands for nutrients and energy. Hematocrit, hemoglobin, and

erythrocyte counts increase as a result of pregnancy adaptations (Mekroud et al., 202).

Monitoring the hematological profile is crucial for assessing animal health and detecting factors causing biomarker alterations like disease, stress, or pregnancy. In ruminants, blood parameters reflect the physiological state, herd management practices, and seasonal variations. Lower red blood cell content may signal anemia, while reduced hematocrit levels may indicate dehydration (Hasan et al., 2021).

Variations in leukocyte levels may point towards infections. Understanding these hematological changes aids in maintaining the health and welfare of dairy cattle while maximizing productivity (Wrzecińska et al., 2023).

Genetics, heat stress, and disease-related issues can all contribute to a decline in reproductive performance. Interestingly, a negative relationship exists between milk production and reproduction, indicating that high milk yield often comes at the cost of reproductive health. The mammary system's substantial nutritional demands affect reproduction physiologically. In particular, highly productive lactating cows consume considerable amounts of glucose, leading to a state of negative energy balance in the early postpartum phase (Sammad et al., 2022).

Metabolic changes in the body of pregnant cows have been reported in many studies (Ott, 2019; Hasan et al., 2021; Zhang et al., 2023). It appears that during the transition period, cows experience various physiological changes and increased energy demands to produce colostrum and milk. This phase involves alterations such as reduced body weight, and higher cortisol levels, and necessitates adequate feed intake for proper adaptation. Inadequate intake, coupled with poor adaptation, can lead to negative energy balance and metabolic issues like increased ketone bodies, hypocalcemia, and weakened immunity. These metabolic and infectious problems can have adverse effects on both reproduction and productivity (Mezzetti et al., 2020).

Dry matter intake tends to be at its lowest during this transition phase, with dairy cows showing a significant reduction, sometimes up to 30 % at parturition. Enzyme activities like (Glutathione Peroxidase) increase during early lactation compared to other periods, showcasing significant changes in antioxidant levels (Zhang et al., 2023).

Non-esterified fatty acids are metabolized by the liver, either as lipoproteins or as oxidized fats. Cows' energy and metabolic status are closely correlated with blood metabolites such as glucose, non-esterified fatty acids, and beta-hydroxybutyrate. Subclinical ketosis is often diagnosed by beta-hydroxybutyrate levels (Zhang et al., 2020).

Low calcium levels during this phase can lead to various complications such as hypocalcemia, displaced abomasum, ketosis, metritis, and placental retention. Ruminants rely on gluconeogenesis, a process crucial for maintaining energy levels, especially during the periparturient period (Masoumi Pour et al., 2022).

The intricate relationship between blood metabolites, liver function, and the onset of postpartum diseases in dairy cows has been previously highlighted in research. Ensuring proper metabolic health during this transition phase is critical for maintaining both reproductive success and productivity in cows.

Calcium plays a crucial role in pregnant cows (skeletal growth), especially around the time of calving, and lactation. Thus, maintaining proper calcium levels is vital for the health of both the cow and the calf during and after pregnancy.

Calcium also plays an important role in restoring the reproductive function of cows (Mahen et al., 2018; Cheng et al., 2023). Studies have shown that serum calcium drops 9 hours before birth and returns to the normal range about 72 hours after birth (Megahed et al., 2018).

We noted changes in serum calcium during the dry season. Similar processes during drought have also been noted in research (Sayiner et al., 2021).

4. Conclusions

Thus, during the pregnancy of cows, body changes occur. From the early period of gestation, throughout the entire period of embryogenesis, there are changes in the system of hematopoiesis, changes in the activity of enzymes, exchange of Ca and P, accompanied by changes in immunological reactions. Such processes are adaptive and ensure maintenance of the homeostasis system.

The perspective of further research will be aimed at studying changes in immunological and biochemical parameters during physiological pregnancy and when it is complicated.

Conflict of interest

The authors declare that there is no conflict of interest.

References

Alhussien, M. N., & Dang, A. K. (2019). Potential roles of neutrophils in maintaining the health and productivity of dairy cows during various physiological and physiopathological conditions: a review. *Immunologic research*, 67(1), 21–38. [Crossref] [Google Scholar]

Alhussien, M. N., Kamboj, A., Aljader, M. A., Panda, B. S. K., Yadav, M. L., Sharma, L., Mohammed, S., Sheikh, A. A., Lotfan, M., Kapila, R., Mohanty, A. K., & Dang, A. K. (2018). Effect of tropical thermal stress on peri-implantation immune responses in cows. *Theriogenology*, 114, 149–158. [Crossref] [Google Scholar]

Cheng, Z., Ferris, C., Crowe, M. A., Ingvartsen, K. L., Grelet, C., Vanlierde, A., & GplusE Consortium. (2023). Hepatic Global Transcriptomic Profiles of Holstein Cows According to Parity Reveal Age-Related Changes in Early Lactation. *International Journal of Molecular Sciences*, 24(12), 9906. [Crossref] [Google Scholar]

Czyżewska-Dors, E., Wierzchosławski, K., & Pomorska-Mól, M. (2022). Serum Concentrations of Immunoglobulins and Cortisol Around Parturition in Clinically Healthy Sows and Sows with Postpartum Dysgalactia Syndrome (PDS). *Journal of veterinary research*, 66(2), 245–250. [Crossref] [Google Scholar]

Fávero, J. F., Da Silva, A. S., Bottari, N. B., Schetinger, M. R. C., Morsch, V. M. M., Baldissera, M. D., Stefani, L. M., & Machado, G. (2018). Physiological changes in the adenosine deaminase activity, antioxidant and inflammatory parameters in pregnant cows and at post-partum. *Journal of Animal Physiology and Animal Nutrition*, 102(4), 910–916. [Crossref] [Google Scholar]

Ferreira, M. F. L., Rennó, L. N., Rodrigues, I. I., Detmann, E., Paulino, M. F., de Campos Valadares Filho, S., Martins, H. C., Moreira, S. S., & de Lana, D. S. (2021). Effects of parity order on performance, metabolic, and hormonal parameters of grazing beef cows during pre-calving and lactation periods. *BMC Veterinary Research*, 17(1), 311. [Crossref] [Google Scholar]

Fiorenza, M. F., Amaral, C. D. S., da Anunciação, A. R. A., Portela, V. V. M., Marey, M. A., Miyamoto, A., & Antoniazzi, A. Q. (2021). Possible impact of neutrophils on immune responses during early pregnancy in ruminants. *Animal Reproduction*, 18(3), e20210048.
[Crossref] [Google Scholar]

Fiorenza, M. F., Marey, M. A., Rashid, M. B., Zinnah, M. A., Ma, D., Morillo, V. A., Kusama, K., Shimada, M., Imakawa, K., Antoniazzi, A. Q., & Miyamoto, A. (2021). Neutrophils recognize and amplify IFNT signals derived from day 7 bovine embryo for stimulation of ISGs expression *in vitro*: A possible implication for the early maternal recognition of pregnancy. *Biochemical and Biophysical Research Communications*, 553, 37–43.
[Crossref] [Google Scholar]

Goldansaz, S. A., Markus, S., Plastow, G., & Wishart, D. S. (2022). Predictive blood biomarkers of sheep pregnancy and litter size. *Scientific Reports*, 12(1), 10307.
[Crossref] [Google Scholar]

Gomaa, N. A., Darwish, S. A., & Aly, M. A. (2021). Immunometabolic response in Egyptian water buffalo cows during the transition period. *Veterinary World*, 14(10), 2678–2685.
[Crossref] [Google Scholar]

Hasan, S., Miah, M. A., & Islam, M. K. (2021). Haemato-biochemical profile during different stages of lactation in local Sahiwal crossbred dairy cows at Savar area of Dhaka district of Bangladesh. *Asian Journal of Medical and Biological Research*, 7(1), 1–5.
[Crossref] [Google Scholar]

Kaiser, M., Jacobson, M., Bækbo, P., Dahl J., Jacobsen, S., Guo, Y. Z., Larsen T., & Andersen, P. H. (2022). Lack of evidence of mastitis as a causal factor for postpartum dysgalactia syndrome in sows. *Transational Animal Science*, 4(1), 250–263.
[Crossref] [Google Scholar]

Kamat, M. M., Vasudevan, S., Maalouf, S. A., Townson, D. H., Pate, J. L., & Ott, T. L. (2016). Changes in Myeloid Lineage Cells in the Uterus and Peripheral Blood of Dairy Heifers During Early Pregnancy. *Biology of Reproduction*, 95(3), 68.
[Crossref] [Google Scholar]

Kowalczyk, A., Czerniawska-Piątkowska, E., & Wrzecińska, M. (2021). The Importance of Interferon-Tau in the Diagnosis of Pregnancy. *BioMed Research International*, 2021, 9915814.
[Crossref] [Google Scholar]

Leppo, K. A., Collins, P. A., Morgado, K. P., Silva, A. C., Thomas, A., & Rutigliano, H. M. (2021). Lymphocyte soluble factors from pregnant cows modulate mRNA transcript abundances encoding for proteins associated with trophoblast growth and development. *Animal reproduction science*, 228, 106747.
[Crossref] [Google Scholar]

Mahen, P. J., Williams, H. J., Smith, R. F., & Grove-White, D. (2018). Effect of blood ionised calcium concentration at calving on fertility outcomes in dairy cattle. *Veterinary Record*, 183(8), 263–263.
[Crossref] [Google Scholar]

Manjari, P., Reddi, S., Alhussien, M., Mohammed, S., De, S., Mohanty, A. K., Sivalingam, J., & Dang, A. K. (2016). Neutrophil gene dynamics and plasma cytokine levels in dairy cattle during peri-implantation period. *Veterinary immunology and immunopathology*, 173, 44–49.
[Crossref] [Google Scholar]

Masoumi Pour, M. M., Foroudi, F., Karimi, N., Abedini, M. R., & Karimi, K. (2022). Effect of Anionic and Zeolite Supplements and Oral Calcium Bolus in Prepartum Diets on Feed Intake, Milk Yield and Milk Compositions, Plasma Ca Concentration, Blood Metabolites and the Prevalence of Some Reproductive Disorders in Fresh Dairy Cows. *Animals*, 12(21), 3059.
[Crossref] [Google Scholar]

Megahed, A. A., Hiew, M. W., El Badawy, S. A., & Constable, P. D. (2018). Plasma calcium concentrations are decreased at least 9 hours before parturition in multiparous Holstein-Friesian cattle in a herd fed an acidogenic diet during late gestation. *Journal of Dairy Science*, 101(2), 1365–1378.
[Crossref] [Google Scholar]

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 & Technology*, 13(1), 28–33.
[Crossref] [Google Scholar]

Mezzetti, M., Bionaz, M., & Trevisi, E. (2020). Interaction between inflammation and metabolism in periparturient dairy cows. *Journal of Animal Science*, 98(Suppl 1), S155–S174.
[Crossref] [Google Scholar]

Mohammed, S., Alhussien, M. N., & Dang, A. K. (2022). Pregnancy stage-dependent modulation of neutrophil function may impact embryo survivability and pregnancy outcome in crossbred cows. *Theriogenology*, 191, 200–206.
[Crossref] [Google Scholar]

Mohapatra, S. K., Panda, B. S. K., Verma, A. K., Kapila, R., & Dang, A. K. (2020). Implantation associated changes in expression profile of indoleamine-2, 3-dioxygenase 1, Th1-Th2 cytokines and interferon-stimulated genes on neutrophils and peripheral blood mononuclear cells of crossbred cows. *Journal of reproductive immunology*, 142, 103188.
[Crossref] [Google Scholar]

Mojsym, W., Wawrzykowski, J., Jamioł, M., Chrobak, Ł., & Kankofer, M. (2022). Comparative Analysis of Saliva and Plasma Proteins Patterns in Pregnant Cows-Preliminary Studies. *Animals*, 12(20), 2850.
[Crossref] [Google Scholar]

Molefe, K., & Mwanza, M. (2020). Variability of serum reproductive hormones in cows presenting various reproductive conditions in semi-arid areas of the North West Province, South Africa. *Veterinary World*, 13(3), 502–507.
[Crossref] [Google Scholar]

Noori Sabzikar, Z., Mohri, M., & Seifi, H. A. (2023). Variations of some adipokines, pro-inflammatory cytokines, oxidative stress biomarkers, and energy characteristics during the transition period in dairy cows. *Veterinary Research Forum*, 14(2), 87–95.
[Crossref] [Google Scholar]

Ott, T. L. (2019). Symposium review: Immunological detection of the bovine conceptus during early pregnancy. *Journal of Dairy Science*, 102(4), 3766–3777.
[Crossref] [Google Scholar]

Perry, G. A., Perkins, S. D., Northrop, E. J., Rich, J. J. J., Epperson, K. M., Andrews, T. N., Kline, A. C., Quail, L. K., Walker, J. A., Wright, C. L., & Russell, J. R. (2021). Impact of trace mineral source on beef replacement heifer growth, reproductive development, and biomarkers of maternal recognition of pregnancy and embryo survival. *Journal of Animal Science*, 99(7), skab160.
[Crossref] [Google Scholar]

Rocha, C. C., da Silveira, J. C., Forde, N., Binelli, M., & Pugliesi, G. (2021). Conceptus-modulated innate immune function during early pregnancy in ruminants: a review. *Animal reproduction*, 18(1), e20200048.
[Crossref] [Google Scholar]

Rutigliano, H. M., Leppo, K. A., & Morgado, K. P. (2022). Changes in mononuclear immune cells during bovine pregnancy. *Reproduction, Fertility, and Development*, 34(8), 608–618.
[Crossref] [Google Scholar]

Sammad, A., Khan, M. Z., Abbas, Z., Hu, L., Ullah, Q., Wang, Y., Zhu, H., & Wang, Y. (2022). Major nutritional metabolic alterations influencing the reproductive system of postpartum dairy cows. *Metabolites*, 12(1), 60.
[Crossref] [Google Scholar]

Sayiner, S., Darbaz, I., Ergene, O., & Aslan, S. (2021). Changes in antioxidant enzyme activities and metabolic parameters in dairy cows during different reproductive periods. *Theriogenology*, 159, 116–122.
[Crossref] [Google Scholar]

Sheikh, A. A., Hooda, O. K., Kalyan, A., Kamboj, A., Mohammed, S., Alhussien, M., Reddi, S., Shimray, P. G., Rautela, A., Pandita, S., Kapila, S., De, S., & Dang, A. K. (2018). Interferon-tau stimulated gene expression: A proxy to predict embryonic mortality in dairy cows. *Theriogenology*, 120, 61–67. [Crossref] [Google Scholar]

Talukder, A. K., Rashid, M. B., Yousef, M. S., Kusama, K., Shimizu, T., Shimada, M., Suarez, S. S., Imakawa, K., & Miyamoto, A. (2018). Oviduct epithelium induces interferon-tau in bovine Day-4 embryos, which generates an anti-inflammatory response in immune cells. *Scientific Reports*, 8(1), 7850. [Crossref] [Google Scholar]

Talukder, M. A. S., Balboula, A. Z., Shirozu, T., Kim, S. W., Kunii, H., Suzuki, T., Ito, T., Kimura, K., & Takahashi, M. (2018). Activation of lysosomal cathepsins in pregnant bovine leukocytes. *Reproduction (Cambridge, England)*, 155(6), 515–528. [Crossref] [Google Scholar]

Tufarelli, V., Colonna, M. A., Losacco, C., & Puvača, N. (2023). Biological Health Markers Associated with Oxidative Stress in Dairy Cows during Lactation Period. *Metabolites*, 13(3), 405. [Crossref] [Google Scholar]

Velázquez, M. M. D. L., Peralta, M. B., Angeli, E., Stassi, A. F., Gareis, N. C., Durante, L., Cainelli, S., Salvetti, N. R., Rey, F., & Ortega, H. H. (2019). Immune status during postpartum, peri-implantation and early pregnancy in cattle: An updated view. *Animal Reproduction Science*, 206, 1–10. [Crossref] [Google Scholar]

Wrzecińska, M., Kowalczyk, A., Czerniawska-Piątkowska, E., Kordan, W., & Araujo, J. P. (2023). Examination of the haematological profile of pregnant Polish Holstein-Friesian black-and-white cattle in the early stage. *Journal of Veterinary Research*, 67(3), 415–425. [Crossref] [Google Scholar]

Zhang, F., Nan, X., Wang, H., Zhao, Y., Guo, Y., & Xiong, B. (2020). Effects of propylene glycol on negative energy balance of postpartum dairy cows. *Animals*, 10(9), 1526. [Crossref] [Google Scholar]

Zhang, M. Q., Heirbaut, S., Jing, X. P., Stefańska, B., Vandaele, L., De Neve, N., & Fievez, V. (2023). Transition cow clusters with distinctive antioxidant ability and their relation to performance and metabolic status in early lactation. *Journal of Dairy Science*, 106, 5723–5739. [Crossref] [Google Scholar]

Zhelavskyi, M., Shunin, I., & Midyk, S. (2020). Extracellular antibacterial defense mechanisms of neutrophil granulocytes and their role in pathogenesis of pyometra (cases) in cats. *Polish Journal of Natural Sciences,* 35(3), 363–378. [Abstract] [Google Scholar]

Zhelavskyi, M. M. (2021). The role of neutrophil on subclinical mastitis in cows. *Polish Journal of Natural Sciences,* 36(1), 107–115. [Abstract] [Google Scholar]

Zhelavskyi, M. M., Kernychnyi, S. P., & Dmytriv, O. Ya. (2021). Cell death and its significance in reproductive pathology. *Ukrainian Journal of Veterinary and Agricultural Sciences,* 4(2), 18–26. [Crossref] [Google Scholar]

Zhelavskyi, M. M., Kernychnyi, S. P., Dmytriv, O. Ya., & Betlinska, T. V. (2022). Cellular aging and immunity. *Ukrainian Journal of Veterinary and Agricultural Sciences,* 5(1), 8–16. [Crossref] [Google Scholar]

Zhelavskyi, M. M., & Dmytriv, O. Ya. (2023). Mammary tumors of the dog and the cat: modern approaches to classification and diagnosis (review). *Scientific Messenger of LNU of Veterinary Medicine and Biotechnologies. Series: Veterinary Sciences,* 25(10), 39–44. [Crossref] [Google Scholar]

Zhelavskyi, M. M., Kernychnyi, S. P., & Betlinska, T.V. (2023). Effects of Hydroxychloroquine and Tacrolimus on Discoid Facial Lupus Erythematosus in a Dog. *World's Veterinary Journal,* 13(2), 360–364. [Crossref] [Google Scholar]

Zhelavskyi, M., Kernychnyi, S., & Betlinska, T. (2023). Hematological and Biochemical Parameters of Macropod Progressive Periodontal Disease in Wild Western Gray Kangaroos. *World's Veterinary Journal,* 13(4), 630–635. [Crossref] [Google Scholar]

Zhelavskyi, M., Kernychnyi, S., Mizyk, V., Dmytriv, O., & Betlinska, T. (2020). The importance of metabolic processes and immune responses in the development of pathology of cows during pregnancy and postpartum periods. *Ukrainian Journal of Veterinary and Agricultural Sciences*, 3(2), 36–41. [Crossref] [Google Scholar]