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Original article

CORRELATION BETWEEN CARDIC RHYTHM PARAMETERS AND CYTOKINE PROFILE LEVELS IN YOUNG CATTLE DURING EARLY NEONATAL ONTOGENESIS

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Abstract

Background. During the growth and development of young cattle, there is a significant association between functional changes in the body and housing conditions, influencing the regulation of immune responses and metabolic processes. In calves kept in natural conditions, the activity of natural immunity regulators prevails, contributing to the optimisation of growth and development processes. At the same time, in young animals exposed to stressful conditions associated with intensive housing methods, a decrease in the activity of these regulators is recorded, which can negatively affect their health and adaptability. Activation of neurohumoral mechanisms, including the influence of the hypothalamic-pituitary system, plays a key role in the regulation of metabolic processes and the immune response in young animals. In calves under stress, an increase in the level of proinflammatory cytokines is noted, which indicates a violation of the physiological balance in the cytokine network. Conversely, in calves kept in more favorable (natural) conditions, a more balanced ratio between pro- and anti-inflammatory cytokines is observed, contributing to the maintenance of homeostasis and improved adaptive responses.

Purpose. The main objective of the present research is to find out the correlation between cardiac rhythm parameters and cytokine profile levels in young cattle during early neonatal ontogenesis.

Materials and methods. To study the nature of the correlation between the parameters of the heart rate and the levels of cytokines in young cattle in early neonatal ontogenesis, 50 one-day-old calves aged 5 days were randomly selected at the premises of Chapaevskoye SP LLC.

In the first experimental group, after calving, the newborn calf underwent a primary veterinary examination, after which it was left in a group with its mother, simulating natural conditions for the entire duration of the experiment.

In the second experimental group, calves were managed according to industrial livestock farming practices. Newborn calves were separated from their mothers immediately after birth and fed with colostrum: two liters within 1-2 hours after birth, followed by an additional two liters by the 12th hour of life. This approach subjected the animals to higher adaptive and domestication stress. Statistical significance was determined in relation to the second experimental group.

The calves of all groups underwent heart rate analysis at 5 days of age; the animals were examined in a standing position, in a stall, and in a lateral lying position on an isolated surface using a diagnostic device, a single-channel electrocardiograph EK1T-07 "Axion".

Blood samples were collected aseptically from the tail vein of each experimental group using S-Monovette 1.2 ml (66x8 mm) KZ-EDTA tubes. In stabilized samples, cytokine levels in blood plasma were measured using flow cytometry on a Bio-Plex Protein Assay System (Bio-Rad, USA). The Human 8-Plex Cytokine Panel reagent kit was used for the analysis according to the manufacturer's instructions. As a result of the study, four types of cytokines were quantitatively measured: interleukin-2 (IL-2), interleukin-4 (IL-4), interleukin-8 (IL-8), and interleukin-10 (IL-10).

To ensure data reliability, cytokine concentrations were determined in three independent experimental series, both for calibration solutions and for the analyzed samples. Quantification was determined in pg/ml using Bio-Plex Manager 6.1 software (Bio-Rad) based on standard calibration curves. The obtained data were processed using descriptive and structural statistics.

To analyze the relationships between various heart rate parameters and cytokine levels in young cattle, the statistical method of Pearson correlation (r) was used, determining the degree and direction of the relationship between variables, which is critical for understanding physiological processes and their impact on animal health.

Results. Increased activity of the autonomic mechanisms regulating heart rate in newborn calves was associated with reduced function of innate immunity regulators (IL-8), specific immune responses (IL-2 and IL-4), and cytokines involved in inflammatory processes (IL-10). A weak relationship was also found between the activity of the autonomic nervous system, reflected in the very low frequency component (VLF) of heart rate variability, and the level of IL-4. The increased influence of the central nervous system on cardiac activity, including activation of the hypothalamic-pituitary axis, is accompanied by an increase in the concentration of

IL-4, which plays an important role in the differentiation of lymphocytes and the development of the immune response, including inflammatory reactions.

Conclusion. Analysis of the heart rate dynamics confirmed that under stress conditions, an activation of the autonomous regulatory circuit is observed, which can negatively affect the health of calves. An increase in the activity of low-frequency waves is associated with increased sympathetic activity and stress, while high-frequency waves correlate with the activity of the parasympathetic nervous system and improved adaptive mechanisms.

Thus, the study highlights the critical importance of optimizing housing conditions for newborn calves. Correction of environmental factors and minimization of stress are essential to ensure harmonious interaction between central and autonomic regulation. This, in turn, can contribute to improved health, strengthening of the immune response and increased survival of newborn offspring, as well as the effectiveness of adaptation of young cattle in early neonatal ontogenesis.

Keywords: cardiac rhythm; cytokine profile levels; cattle; neonatal ontogenesis

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Научная статья

КОРРЕЛЯЦИЯ МЕЖДУ ПАРАМЕТРАМИ КАРДИАЛЬНОГО РИТМА И УРОВНЕМ ЦИТОКИНОВОГО ПРОФИЛЯ У МОЛОДНЯКА КРУПНОГО РОГАТОГО СКОТА В РАННЕМ НЕОНАТАЛЬНОМ ОНТОГЕНЕЗЕ

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Аннотация

Обоснование. В период роста и развития молодняка крупного рогатого скота существует значительная связь между функциональными изменениями в организме и условиями содержания, влияющими на регуляцию иммунных реакций и метаболических процессов. У телят, содержащихся в естествен-

ных условиях, преобладает активность естественных регуляторов иммунитета, способствующая оптимизации процессов роста и развития. В то же время у молодняка, подверженного стрессовым условиям, связанным с интенсивными методами содержания, отмечается снижение активности этих регуляторов, что может негативно сказаться на их здоровье и адаптивности. Активация нейрогуморальных механизмов, включая влияние гипоталамо-гипофизарной системы, играет ключевую роль в регуляции метаболических процессов и иммунного ответа у молодняка. У телят, подвергнутых стрессу, отмечается повышение уровня провоспалительных цитокинов, что свидетельствует о нарушении физиологического баланса в цитокиновой сети. И наоборот, у телят, содержащихся в более благоприятных (естественных) условиях, наблюдается более сбалансированное соотношение между про- и противовоспалительными цитокинами, способствующее поддержанию гомеостаза и улучшению адаптивных реакций.

Цель. Основная цель настоящего исследования – выявить корреляцию между параметрами сердечного ритма и уровнем цитокинового профиля у молодняка крупного рогатого скота в раннем неонатальном онтогенезе.

Материалы и методы. Для изучения характера взаимосвязи между параметрами сердечного ритма и уровнем цитокинов у молодняка крупного рогатого скота в раннем неонатальном онтогенезе на территории ООО «Чапаевское СП» случайным образом были отобраны 50 однодневных телят в возрасте 5 дней.

В первой опытной группе после отела новорожденный теленок проходил первичный ветеринарный осмотр, после чего его оставляли в группе с матерью, имитируя естественные условия на весь период эксперимента.

Во второй экспериментальной группе уход за телятами осуществлялся в соответствии с практикой промышленного животноводства. Новорожденных телят отделяли от матери сразу после рождения и кормили колострумом: два литра в течение 1-2 часов после рождения, а затем еще два литра к 12-му часу жизни. Такой подход подвергал животных повышенному адаптационному и одомашненному стрессу. Статистическую значимость определяли по отношению ко второй опытной группе.

Телятам всех групп в 5-дневном возрасте проводили исследование сердечного ритма в положении стоя, в стойле и в положении лежа на боку на изолированной поверхности с помощью диагностического прибора – одноканального электрокардиографа ЭК1Т-07 «Аксион».

Образцы крови собирали асептически из хвостовой вены каждой экспериментальной группы с помощью пробирок S-Monovette объемом 1,2 мл (66х8 мм) с KZ-EDTA. В стабилизированных образцах уровень цитокинов в плазме

крови измеряли методом проточной цитометрии на приборе Bio-Plex Protein Assay System (Bio-Rad, США). Для анализа использовали набор реагентов Human 8-Plex Cytokine Panel в соответствии с инструкцией производителя. В результате исследования было проведено количественное определение четырех типов цитокинов: интерлейкина-2 (ИЛ-2), интерлейкина-4 (ИЛ-4), интерлейкина-8 (ИЛ-8) и интерлейкина-10 (ИЛ-10).

Для обеспечения достоверности данных концентрацию цитокинов определяли в трех независимых экспериментальных сериях, как для калибровочных растворов, так и для анализируемых образцов. Количественное определение проводили в пг/мл с помощью программы Bio-Plex Manager 6.1 (Bio-Rad) на основе стандартных калибровочных кривых. Полученные данные обрабатывали с помощью описательной и структурной статистики.

Для анализа взаимосвязи между различными параметрами сердечного ритма и уровнем цитокинов у молодняка крупного рогатого скота использовали статистический метод корреляции Пирсона (r), определяющий степень и направление связи между переменными, что крайне важно для понимания физиологических процессов и их влияния на здоровье животных.

Результаты. Повышенная активность вегетативных механизмов, регулирующих частоту сердечных сокращений, у новорожденных телят была связана со снижением функции регуляторов врожденного иммунитета (IL-8), специфических иммунных реакций (IL-2 и IL-4) и цитокинов, участвующих в воспалительных процессах (IL-10). Также была выявлена слабая связь между активностью вегетативной нервной системы, отраженной в очень низкочастотной составляющей (VLF) вариабельности сердечного ритма, и уровнем IL-4. Усиление влияния центральной нервной системы на сердечную деятельность, включая активацию гипоталамо-гипофизарной оси, сопровождается повышением концентрации IL-4, который играет важную роль в дифференцировке лимфоцитов и развитии иммунного ответа, в том числе воспалительных реакций.

Заключение. Анализ динамики сердечного ритма подтвердил, что в условиях стресса наблюдается активация автономного контура регуляции, что может негативно сказаться на здоровье телят. Повышение активности низкочастотных волн связано с усилением симпатической активности и стрессом, в то время как высокочастотные волны коррелируют с активностью парасимпатической нервной системы и улучшением адаптивных механизмов.

Таким образом, данное исследование подчеркивает исключительную важность оптимизации условий содержания новорожденных телят. Коррекция факторов окружающей среды и минимизация стресса необходимы для обеспечения гармоничного взаимодействия между центральной и вегетативной

регуляцией. Это, в свою очередь, может способствовать улучшению здоровья, усилению иммунного ответа и повышению выживаемости новорожденного потомства, а также эффективности адаптации молодняка крупного рогатого скота в раннем неонатальном онтогенезе.

Ключевые слова: сердечный ритм; уровни цитокинового профиля; крупный рогатый скот; неонатальный онтогенез

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Introduction

During ontogenesis, animals undergo interrelated changes in morphology, biochemistry, and body functions. Understanding changes in functional and biochemical blood parameters in cattle is an important element for targeted breeding of young animals and maintaining the health of dairy herds. Optimal parameters at all stages of individual development are the key to maximizing genetic potential [1; 11].

Cytokines are proteins that serve as chemical messengers that regulate the innate and adaptive immune response. Changes in blood cytokine levels provide valuable information for understanding pathophysiological processes and monitoring disease progression and inflammation [6; 7]. Recent trends in scientific research have focused on cytokines and their importance in the pathogenesis of many diseases. This has led to an intensification of the study of their functions and interactions in the context of various pathologies, among which infectious diseases occupy a special place. Evaluation of the cytokine profile in the blood serum of calves has practical significance, since it allows predicting the ineffectiveness of preventive programs and making the necessary adjustments in the preventive and therapeutic approach [2; 15].

The study of electrocardiographic parameters and heart rate variability plays an important role in diagnostics, enabling the assessment of vegetative homeostasis and the functional capabilities of the cardiovascular system in animals. The indicators of variation pulsometry of the heart rate systematically change depending on the type of vegetative regulation affecting the work of the heart [9; 12].

Cardiac rhythm, determined by the frequency and regularity of heart contractions, is regulated by a complex network of neurohumoral factors and autonomic regulation. In neonatal calves, the establishment of a stable cardiac rhythm is

necessary for optimal physiological functioning, since any violation can lead to a deterioration in health. Understanding the correlation between cardiac parameters and cytokine levels during this critical period of development can provide important information about the overall health and resilience of young animals [3; 8; 14].

Cytokines, which act as key mediators of the immune response, affect various physiological processes including inflammation, growth and metabolism. Their levels can serve as indicators of the health of the animal and its ability to adapt to external stress factors [4; 11]. At the same time, cardiac parameters such as heart rate and variability are important indicators of cardiovascular health and can reflect the animal's response to stress and immune challenges [5; 9; 14].

The early neonatal period in cattle is characterized by rapid physiological changes that are critical for survival and development. During this period, the correlation between cardiac parameters and cytokine levels becomes an important issue, since both factors have a significant impact on the overall health and well-being of young animals. Studies show that during this period, young animals are exposed to various stress factors, including changes in temperature, housing conditions, and interaction with their mother, which can affect their immune status and cardiovascular system [4,5,13]. Thus, studying the correlation between heart rate parameters and the level of the cytokine profile in young cattle in early neonatal ontogenesis can help improve the diagnosis and prognosis of diseases, as well as determine the effectiveness of preventive measures.

Purpose. The main objective of the present research is to find out the correlation between cardiac rhythm parameters and cytokine profile levels in young cattle during early neonatal ontogenesis.

Materials and methods

To study the nature of the correlation between the parameters of the heart rate and the levels of cytokines in young cattle in early neonatal ontogenesis, 50 one-day-old calves aged 5 days were randomly selected at the premises of Chapaevskoye SP LLC.

In the first experimental group, after calving, the newborn calf underwent a primary veterinary examination, after which it was left in a group with its mother, simulating natural conditions for the entire duration of the experiment.

In the second experimental group, calves were managed according to industrial livestock farming practices. Newborn calves were separated from their mothers immediately after birth and fed with colostrum: two liters within 1-2 hours after birth, followed by an additional two liters by the 12th hour of life. This approach subjected the animals to higher adaptive and domestication

stress. Statistical significance was determined in relation to the second experimental group.

The calves of all groups underwent heart rate analysis at 5 days of age; the animals were examined in a standing position, in a stall, and in a lateral lying position on an isolated surface using a diagnostic device, a single-channel electrocardiograph EK1T-07 "Axion".

Blood samples were collected aseptically from the tail vein of each experimental group using S-Monovette 1.2 ml (66x8 mm) KZ-EDTA tubes. In stabilized samples, cytokine levels in blood plasma were measured using flow cytometry on a Bio-Plex Protein Assay System (Bio-Rad, USA). The Human 8-Plex Cytokine Panel reagent kit was used for the analysis according to the manufacturer's instructions. As a result of the study, four types of cytokines were quantitatively measured: interleukin-2 (IL-2), interleukin-4 (IL-4), interleukin-8 (IL-8), and interleukin-10 (IL-10).

To ensure data reliability, cytokine concentrations were determined in three independent experimental series, both for calibration solutions and for the analyzed samples. Quantification was determined in pg/ml using Bio-Plex Manager 6.1 software (Bio-Rad) based on standard calibration curves. The obtained data were processed using descriptive and structural statistics.

To analyze the relationships between various heart rate parameters and cytokine levels in young cattle, the statistical method of Pearson correlation (r) was used, determining the degree and direction of the relationship between variables, which is critical for understanding physiological processes and their impact on animal health.

Results

In the process of studying the cytokine profile of young cattle in the early neonatal period, kept in simulated natural conditions, as well as within the framework of industrial livestock farming technology, statistically significant changes in the levels of interleukins IL-2, IL-4, IL-8 and IL-10 were identified (Table 1).

Table 1.

Interleukin levels in calves of the study groups

Interleukin (pg/ml)	First experimental group	Second experimental group	Background norm
IL-2	30.5+0.05	34.8+0.05	20-25
IL-4	23.8+0.04	29.5+0.04	15-20
IL-8	31.1+0.06	48.7+0.06	20-25
IL-10	19.3+0.03	26.1+0.03	10-15

According to the data presented in Table 1, the level of interleukin 2 (IL-2) in the calves of the first experimental group was 30.5±0.05 pg/ml, which is 1.22 times higher than the background level. This indicates a significant activation of T-lymphocyte proliferation, which may be associated with adaptation to the living conditions. The level of interleukin 4 (IL-4) was recorded at 23.8±0.04 pg/ml (exceeding the background level by 1.19 times), indicating active differentiation of T-helpers and increased humoral immune response. The concentration of interleukin 8 (IL-8) was 42.1±0.06 pg/ml, which is 1.24 times higher than the background level, indicating the presence of an inflammatory reaction, although to a lesser extent compared to the second group. The level of interleukin 10 (IL-10) was 24.3±0.03 pg/ml (exceeding the background norm by 1.29 times), which confirms its role in the regulation of inflammatory processes and the protective function of the body.

At the same time, in calves of the second experimental group, the level of IL-2 was 34.8±0.05 pg/ml, which exceeds the background norm by 1.39 times, indicating a higher activity of T-lymphocyte proliferation. The level of IL-4 was also elevated, amounting to 29.5±0.04 pg/ml (exceeding the background norm by 1.48 times), which indicates a significant increase in the humoral immune response under the influence of stressful conditions associated with separate housing of calves and early feeding with colostrum. The IL-8 concentration reached 48.7±0.06 pg/ml, which is 1.95 times higher than the control values, reflecting pronounced inflammation and active participation of neutrophils in the immune response. The IL-10 level in this group was 26.1±0.03 pg/ml (exceeding the background norm by 1.74 times), which is also higher than in the first group, confirming the presence of a more pronounced inflammatory response and activation of inflammatory regulation mechanisms.

Analysis of interleukin levels revealed that in the first experimental group, where the calves were with their mother, exhibited lower levels of inflammatory markers, such as interleukin-2 and interleukin-4, indicating a more stable immune response. While in the second group, where the calves were raised according to industrial livestock technology, the level of these cytokines was significantly higher. This may indicate the development of acute inflammatory processes. In addition, the levels of interleukin-8 and -10 were also elevated in this group, which serves as additional confirmation of the presence of inflammatory reactions.

During the analysis of the dynamics of cardiac rhythm regulation dynamics in newborn calves under two different housing conditions, specific characteris-

tics of their physiological state were identified. In the first experimental group, where the calves were kept with their mother, the predominance of central mechanisms in cardiac rhythm regulation was observed. This is due to the fact that natural housing conditions contributed to a decrease in stress and activation of mechanisms responsible for the harmonization of the cardiovascular system. While in the second experimental group, where the calves were taken from their mother immediately after calving and fed with collected colostrum, activation of the autonomous cardiac rhythm regulation circuit was recorded. This indicates increased adaptive-domestication pressure, which could lead to a state of "tension" in the regulatory systems.

Spectral analysis of heart rate variability revealed that young animals with elevated cytokine levels exhibited increased activity in both low-frequency (LF) and high-frequency (HF) waves. This indicates the active participation of both the central and autonomous cardiac rhythm regulation circuits. In particular, it was found that with an increase in the level of IL-2 and IL-4, a positive correlation with high-frequency waves is observed, which may indicate greater activity of the parasympathetic nervous system and improved adaptive mechanisms. At the same time, an increase in the levels of IL-8 and IL-10 is associated with the activation of low-frequency waves, which may indicate stress reactions and increased sympathetic activity.

Comparison of heart rate parameters and cytokine levels confirmed the presence of weak negative relationships between high-frequency waves and levels of inflammatory markers in the second group. This highlights the importance of choosing optimal housing conditions for newborn calves, as these can significantly influence their health and adaptation in early life (Fig. 1).

According to the graph, in the first experimental group it was found that all the studied cytokines demonstrate a negative correlation with the heart rate. This indicates that the increase in the levels of these interleukins leads to a decrease in low-frequency (LF) and high-frequency (HF) waves, which may indicate a depressing effect of inflammatory processes on the cardiovascular system of calves. Particularly noticeable is the effect of IL-2, which showed the greatest negative relationship, which may indicate its important role in regulating the heart rate under inflammatory or stressful conditions.

In the second group, a positive relationship was recorded between all the studied cytokines and the heart rate. This indicates that the increase in interleukin levels is associated with an increase in the activity of low-frequency (LF) and high-frequency (HF) waves of the heart rate, which is due to the activation of compensatory mechanisms of the body aimed at maintaining homeostasis

under stress or changes in the physiological state. This positive interaction may indicate that increased levels of interleukins such as IL-2, IL-4, IL-8 and IL-10 may serve as indicators of adaptive responses of the body that contribute to the improvement of cardiac activity in response to stress factors.

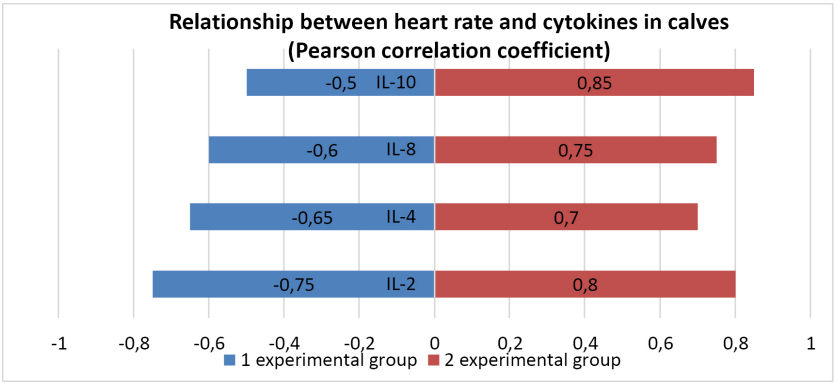

Fig. 1. Correlation between heart rate parameters and cytokine profile in calves according to Pearson

Thus, increased activity of the autonomic mechanisms regulating heart rate in newborn calves was associated with reduced function of innate immunity regulators (IL-8), specific immune responses (IL-2 and IL-4), and cytokines involved in inflammatory processes (IL-10). A weak relationship was also found between the activity of the autonomic nervous system, reflected in the very low frequency component (VLF) of heart rate variability, and the level of IL-4. The increased influence of the central nervous system on cardiac activity, including activation of the hypothalamic-pituitary axis, is accompanied by an increase in the concentration of IL-4, which plays an important role in the differentiation of lymphocytes and the development of the immune response, including inflammatory reactions.

Conclusion

The study showed that the studied groups of calves had increased levels of interleukins, indicating activation of their immune system. The second group showed a more pronounced immune response, with an increase in the levels of IL-2, IL-4, IL-8 and IL-10, exceeding the norm by 1.39, 1.48, 1.95 and 1.74 times, respectively. This indicates a more intense inflammatory response and activation of T-lymphocytes under stress. The findings underscore the importance

of monitoring the immune status of animals to improve their overall health and productivity. Furthermore, they confirm that stress factors significantly impact the immune response in calves.

As a result of the study on the correlation between the parameters of the heart rate and the level of the cytokine profile in young cattle in early neonatal ontogenesis under various conditions of maintenance, significant differences in the immune response and physiological state of the animals were revealed. It was found that calves kept with their mother demonstrated a more stable immune response with low levels of inflammatory markers, indicating less stress and better adaptation to the environment. At the same time, calves exposed to stressful conditions of separate housing and early feeding showed increased levels of interleukins, such as IL-2, IL-4, IL-8 and IL-10, indicating activation of acute inflammatory processes and stress reactions.

Analysis of the heart rate dynamics confirmed that under stress conditions, an activation of the autonomous regulatory circuit is observed, which can negatively affect the health of calves. An increase in the activity of low-frequency waves is associated with increased sympathetic activity and stress, while high-frequency waves correlate with the activity of the parasympathetic nervous system and improved adaptive mechanisms.

Thus, the study highlights the critical importance of optimizing housing conditions for newborn calves. Correction of environmental factors and minimization of stress are essential to ensure harmonious interaction between central and autonomic regulation. This, in turn, can contribute to improved health, strengthening of the immune response and increased survival of newborn offspring, as well as the effectiveness of adaptation of young cattle in early neonatal ontogenesis.

Conflict of interest information. The authors declare that they have no conflict of interest.

References

1. Ip, W. K. E., Hoshi, N., Shouval, D. S., Snapper, S., & Medzhitov, R. (2017). Anti-inflammatory effect of IL-10 mediated by metabolic reprogramming of macrophages. *Science*, *356*, 513–519. https://doi.org/10.1126/science.aal3535
2. Beheshtipour, J., & Raeeszadeh, M. (2020). Evaluation of interleukin-10 and pro-inflammatory cytokine profile in calves naturally infected with neonatal calf diarrhea syndrome. *Archives of Razi Institute*, *75*, 213–218. https://doi.org/10.22092/ARI.2018.124058.1270

3. Osorio, J. S. (2020). Gut health, stress, and immunity in neonatal dairy calves: the host side of host-pathogen interactions. *Journal of Animal Science and Biotechnology*, *11*, 105. https://doi.org/10.1186/s40104-020-00509-3. EDN: https://elibrary.ru/RSFFHA
4. Go, H., Saito, Y., Maeda, H., Maeda, R., Yaginuma, K., Ogasawara, K., Kashiwabara, N., Kawasaki, Y., & Hosoya, M. (2021). Serum cytokine profiling in neonates with hypoxic ischemic encephalopathy. *Journal of Neonatal-Perinatal Medicine*, *14*(2), 177–182. https://doi.org/10.3233/NPM-200431. EDN: https://elibrary.ru/PTOKWC
5. Caliskan, M., Dabak, M., & Tumer, K. C. (2023). The relationship between serum cytokine profile and vitamin D in calves with neonatal diarrhea. *Cytokine*, *165*, 156173. https://doi.org/10.1016/j.cyto.2023.156173. EDN: https://elibrary.ru/NFSFHR
6. Wang, Y., et al. (2022). The relationship between cytokine levels and heart rate in neonatal calves. *Journal of Animal Science*, *100*(2), 1234–1242.
7. Kitajima, K., Oishi, K., Kojima, T., et al. (2022). An assessment of stress status in fattening steers by monitoring heart rate variability: a case of dietary vitamin A restriction. *Frontiers in Animal Science*, *2*, 799289. https://doi.org/10.3389/fanim.2021.799289. EDN: https://elibrary.ru/KSYOTS
8. von Borell, E., Langbein, J., Després, G., et al. (2007). Heart rate variability as a measure of autonomic regulation of cardiac activity for assessing stress and welfare in farm animals — a review. *Physiology & Behavior*, *92*, 293–316. https://doi.org/10.1016/j.physbeh.2007.01.007. EDN: https://elibrary.ru/PGAFYE
9. Li, Y., Zhang, Y., & Wang, J. (2023). Cardiovascular responses and immune status in cattle under stress conditions. *BMC Veterinary Research*, *19*(1), 54. https://doi.org/10.1186/s12917-023-03754-6
10. von Borell, E., Langbein, J., Després, G., et al. (2017). Heart rate variability as a measure of autonomic regulation of cardiac activity for assessing stress and welfare in farm animals — a review. *Physiology & Behavior*, *92*, 293–316. https://doi.org/10.1016/j.physbeh.2007.01.007. EDN: https://elibrary.ru/PGAFYE
11. Blum, J. W., & Hammon, H. M. (n.d.). Colostrum effects on the gastrointestinal tract and on nutritional, endocrine and metabolic parameters in neonatal calves. *Livestock Production Science*, *66*, 151–159.
12. Brăslăşu, M. C. (2000). Electrocardiographic researches on new-born calves. *Revista Română de Medicină Veterinară*, *10*(4), 401–405.
13. Chua, B., Coenen, E., van Delen, J., et al. (2002). Effects of pair versus individual housing on the behavior and performance of dairy calves. *Journal of Dairy Science*, *85*, 360–364.

14. Brăslăşu, E. D., Joija, S., Simiz, F., & Brăslăşu, M. C. (2014). Electrocardiographic parameters in new-born calves (172 cases). *Lucrări Ştiinţifice — Universitatea de Ştiinţe Agricole a Banatului Timişoara, Medicina Veterinară*, *47*(4), 14–19.
15. Gesser, B., Lund, M., Lohse, N., et al. (1996). IL-8 induces T cell chemotaxis, suppresses IL-4, and up-regulates IL-8 production by CD4+ T cells. *Journal of Leukocyte Biology*, *59*(3), 407–411.

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