

Науковий вісник Львівського національного університету
ветеринарної медицини та біотехнологій імені С.З. Гжицького.

Серія: Ветеринарні науки

Scientific Messenger of Lviv National University
of Veterinary Medicine and Biotechnologies.

Series: Veterinary sciences

ISSN 2518–7554 print
ISSN 2518–1327 online

doi: 10.32718/nvlvet12032
<https://nvlvet.com.ua/index.php/journal>

UDC 636.2:612.11:577.1:504.5

Morphological and biochemical blood parameters of young cattle under conditions of technogenic load

S. O. Slobodian[✉], B. V. Gutyj, A. A. Kashchak, T. V. Martyshuk, I. I. Khariv, R. M. Ivashkiv

Stepan Gzhytskyi National University of Veterinary Medicine and Biotechnologies, Lviv, Ukraine

Article info

Received 23.10.2025

Received in revised form

24.11.2025

Accepted 25.11.2025

Stepan Gzhytskyi National
University of Veterinary Medicine
and Biotechnologies Lviv,
Pekarska Str., 50, Lviv,
79010, Ukraine.
Tel.: +38-067-316-74-30
E-mail: solomiaslobodian@ukr.net

Slobodian, S. O., Gutyj, B. V., Kashchak, A. A., Martyshuk, T. V., Khariv, I. I., & Ivashkiv, R. M. (2025). Morphological and biochemical blood parameters of young cattle under conditions of technogenic load. Scientific Messenger of Lviv National University of Veterinary Medicine and Biotechnologies. Series: Veterinary sciences, 27(120), 258–263. doi: 10.32718/nvlvet12032

The increase in technogenic load on agroecosystems, particularly the contamination of the feed base with heavy metals, represents a significant risk to the health and productivity of young cattle. Lead and cadmium, accumulating in feeds, can disrupt hematopoiesis, immune reactivity, protein and enzymatic metabolism, which is reflected in changes in morphological and biochemical blood parameters. Therefore, assessment of the hematological and biochemical blood profile of young cattle kept in areas with different levels of technogenic load is an informative approach for the early detection of functional disorders and justification of preventive measures. The aim of the study was to determine the characteristics of morphological and biochemical blood parameters of young cattle kept in different zones of technogenic load and to evaluate their relationship with the functional state of the hematopoietic system, immune defense, and liver. The study was conducted at the facilities of the agricultural cooperatives “Nyva” and “Ukraina” in the Rivne region. A high content of lead and cadmium in feeds was detected at “Ukraina”, with different accumulation intensities depending on feed type: the highest cadmium levels were found in grain and concentrated feeds (exceeding the maximum permissible levels by 1.23–1.39 times), whereas lead predominantly accumulated in succulent feeds and green forage (exceeding the MPL by 69.2–79.1 %). Black-and-white breed bull calves were selected for the experiment considering age and live weight ($n = 10$ in each group). In stabilized blood, hemoglobin content and the number of erythrocytes and leukocytes were determined using a Mythic-18 hematology analyzer. In blood serum, total protein, protein fractions, and aminotransferase activity were assessed according to the method of Vlislo V. (2012). In young cattle kept under conditions of increased technogenic load (“Ukraina”), compared with animals from “Nyva”, a decrease in erythrocyte count by 7.4% and hemoglobin concentration by 7.1 % was observed, indicating suppression of erythropoiesis and reduced oxygen-transport function of the blood under technogenic stress. The leukocyte count was higher by 13.5 %, which may indicate immune system tension and activation of protective mechanisms in response to environmental stress. Protein metabolism parameters were characterized by a decrease in serum total protein concentration by 5.9 % and a reduction in albumin fraction by 5.7 %, reflecting impairment of the protein-synthesizing function of the liver. At the same time, an increase in the γ -globulin fraction by 8.6 % was noted, indicating activation of the humoral immune response. Aminotransferase activity in the blood of animals from “Ukraina” was significantly higher than in cattle from “Nyva”: AST activity increased by 9.1 % and ALT by 11.9 %, indicating functional liver strain and intensification of metabolic processes under technogenic load. Keeping young cattle in areas with increased technogenic load is associated with reduced erythrocyte indices and protein metabolism markers, increased leukocyte count and γ -globulin fraction, as well as elevated aminotransferase activity, which together reflect the development of adaptive-compensatory responses and functional liver stress. The obtained data substantiate the expediency of regular hematological and biochemical monitoring of young cattle in technogenically loaded areas.

Key words: young cattle, technogenic load, lead, cadmium, hematological parameters, protein fractions, AST, ALT, adaptation, liver.

Морфологічні та біохімічні показники крові молодняку великої рогатої худоби в умовах техногенного навантаження

С. О. Слободян[✉], Б. В. Гутий, А. А. Кашак, Т. В. Мартишук, І. І. Харів, Р. М. Івашків

Львівський національний університет ветеринарної медицини та біотехнологій імені С. З. Гжицького, м. Львів, Україна

Зростання техногенного навантаження на агрокосистеми, зокрема забруднення кормової бази важкими металами, є важливим ризиком для здоров'я та продуктивності молодняку великої рогатої худоби. Свинець і кадмій, накопичуючись у кормах, можуть порушувати процеси кровотворення, імунну реактивність, білковий та ферментативний обмін, що відображається у змінах морфологічних і біохімічних показників крові. Тому оцінка гематологічного та біохімічного профілю крові молодняку ВРХ, який утримується в зонах із різним рівнем техногенного навантаження, є інформативним підходом для раннього виявлення функціональних порушень і обґрунтування профілактичних заходів. Мета дослідження – визначити особливості морфологічних і біохімічних показників крові молодняку великої рогатої худоби, яких утримують у різних зонах техногенного навантаження, та оцінити їх зв'язок із функціональним станом систем кровотворення, імунного захисту та печінки. Дослідження виконано на базі СВК “Нива” та СП “Україна” Рівненської області. У СП “Україна” встановлено високий вміст свинцю та кадмію в кормах із різною інтенсивністю накопичення залежно від виду кормів: найбільші рівні кадмію виявляли у зернових і концентрованих кормах (перевищення максимально допустимих рівнів у 1,23–1,39 раза), тоді як свинець переважно накопичувався в соковитих кормах і зеленій масі (перевищення МДР у межах 69,2–79,1 %). Для дослідів відібрано буайців чорно-рябої породи з урахуванням віку та живої маси ($n = 10$ у кожній групі). У стабілізованій крові визначали вміст гемоглобіну, кількість еритроцитів і лейкоцитів за допомогою гематологічного аналізатора Mythic-18. У сироватці крові досліджували загальний протеїн, білкові фракції та активність амінотрансфераз за методикою описаною в довіднику Влізла В. В. (2012). У молодняку великої рогатої худоби, який утримувався в зоні підвищеного техногенного навантаження (СП “Україна”), порівняно з тваринами СВК “Нива” встановлено зниження кількості еритроцитів на 7,4 % та рівня гемоглобіну на 7,1 %, що вказує про пригнічення еритропоєзу й зменшення киснетранспортної функції крові в умовах дії техногенних чинників. Кількість лейкоцитів у крові молодняку СП “Україна” була вищою на 13,5 %, що може вказувати на напруження імунної системи та активацію захисних механізмів організму у відповідь на екологічний стрес. Показники білкового обміну характеризувалися зниженням рівня загального протеїну в сироватці крові на 5,9 % та зменшення частки альбумінів на 5,7 %, що відображає порушення протеїнсинтезувальної функції печінки. Водночас у тварин із зони підвищеного техногенного навантаження відзначено збільшення частки γ -глобулінів на 8,6 %. Активність амінотрансфераз у крові молодняку СП “Україна” була достовірно вищою порівняно з тваринами СВК “Нива”: активність АСАТ зросла на 9,1 %, а АЛАТ – на 11,9 %, що вказує на функціональне напруження печінки та інтенсифікацію метаболічних процесів за умов техногенного навантаження. Утримання молодняку ВРХ у зоні підвищеного техногенного навантаження асоціюється зі зниженням еритроцитарних показників і маркерів білкового обміну, підвищенням лейкоцитів і γ -глобулінів, а також зростанням активності амінотрансфераз, що в сукупності відображає формування адаптаційно-компенсаторних реакцій організму та функціональну напругу печінки. Отримані дані обґрунтовують доцільність регулярного гематологічного і біохімічного моніторингу молодняку ВРХ у зонах техногенного навантаження.

Ключові слова: молодняк великої рогатої худоби, техногенне навантаження, свинець, кадмій, гематологічні показники, білкові фракції, АСАТ, АЛАТ, адаптація, печінка.

Introduction

The intensification of agricultural production under conditions of increasing anthropogenic and technogenic pressure on the environment necessitates a deeper study of the adaptive capacities of animal organisms (Gutyj et al., 2019; Ostapyuk et al., 2025). Environmental pollution with heavy metals, industrial emissions, agrochemicals, and other xenobiotics adversely affects metabolism, the functional state of organs and systems (Gutyj et al., 2017; Shchepentovska & Kostyniuk, 2020; Grymak et al., 2025; Vus et al., 2025), as well as the level of nonspecific resistance of young cattle.

One of the most widespread types of pollution is the release of significant amounts of heavy metals into the natural environment, which in terms of ecological hazard are second only to pesticides. Heavy metals are capable of accumulating in the bodies of productive animals, and due to their widespread distribution and accumulation in environmental components, especially soils, they can be classified as priority environmental pollutants (Slobodian et al., 2019; Lavryshyn et al., 2020; Nordberg & Nordberg, 2022; Kraikivska et al., 2023).

An increase in heavy metal content in soils leads to enhanced uptake by plants and subsequent accumulation

in food chains (Zheng et al., 2021; Kailasam & Peiter, 2021; Smychok et al., 2023). Heavy metal toxicity is determined by their electronic configuration, electronegativity, redox potential, ionization capacity, affinity for specific chemical groups, ability to penetrate cell membranes and form complexes on the cell surface and inside the cell, as well as by the structural and functional organization of the biological system (Bashchenko et al., 2020; Gul et al., 2021; Kar & Patra, 2021).

The problem of environmental pollution has intensified interest in studying heavy metals, particularly cadmium and lead, as stress factors and in identifying the mechanisms by which organisms protect themselves from their toxic effects (Ozturk et al., 2021; Rezapour et al., 2021; Ostapyuk et al., 2023). Therefore, over recent decades, the research focus of many scientists has been directed toward investigating the effects of pollutants on living organisms, especially productive animals (Slivinska et al., 2019).

The accumulation of cadmium and lead in components of the natural environment increases the risk of their entry into animal organisms and poses a serious threat to animal health (Shiyntum & Ushakova, 2015; Akter et al., 2019). Numerous experimental studies indicate that in mammals, cadmium and lead exert toxic effects on a wide

range of organs and systems (Zeng et al., 2021; Zhao et al., 2021; Gutyj et al., 2022, 2023; Ostapyuk et al., 2024).

Young cattle are particularly sensitive to the action of adverse environmental factors, as their organisms are at the stage of intensive growth and formation of physiological and adaptive mechanisms. Prolonged exposure to technogenic load can lead to the development of oxidative stress, disturbances in hematopoiesis, immune responses, and liver functional activity, which subsequently negatively affect animal productivity and viability.

One of the most informative and objective methods for assessing the physiological state of animals, the level and direction of metabolic processes, as well as for early diagnosis of homeostasis disturbances, is the analysis of morphological and biochemical blood parameters (Slivinska et al., 2019). Blood, as a highly organized tissue, rapidly responds to adverse environmental factors, reflecting changes in hematopoietic, immune, protein, and enzymatic systems. At the same time, its composition is characterized by relative stability under physiological conditions, making hematological and biochemical indices reliable markers of the functional state of the organism (Kowalczyk et al., 2021).

Numerous studies have demonstrated that long-term maintenance of animals in areas with increased technogenic load is accompanied by reduced erythropoiesis intensity, impaired protein-synthesizing liver function, changes in enzyme system activity, and immune response tension (Martyschuk et al., 2020; Mylostyvyi et al., 2021).

In this context, the study of morphological and biochemical blood parameters of young cattle reared in farms located in areas with different levels of technogenic load is highly relevant, aiming to assess the adaptive potential of the organism and to enable early detection of metabolic and functional disorders.

Research objective

The aim of the study was to determine the characteristics of morphological and biochemical blood parameters of young cattle kept in different zones of technogenic load and to evaluate their relationship with the functional state of the hematopoietic system, immune defense, and liver.

Materials and Methods

All experimental procedures were performed in accordance with the European Convention for the Protection of Vertebrate Animals Used for Experimental and Other Scientific Purposes (Strasbourg, 1986).

The study was conducted at the facilities of the agricultural cooperatives “Nyva” (Dubno District) and “Ukraine” (Dubrovytsia District) of the Rivne Region. A high content of lead and cadmium in feeds was detected at “Ukraine”. At the same time, significant differences in the accumulation of these metals were identified among different feed types. The highest cadmium levels were found in grain and concentrated feeds, where its concentration exceeded the maximum permissible levels by 1.39 times (wheat), 1.35 times (rye), and 1.23 times (barley). Regarding lead content, the highest concentrations were detected in succulent feeds, particularly in sugar beet tops

by 79.1 %, green mass of natural pasture grasses by 69.3 % and 76.4 %, and green mass of vetch–oat mixture by 69.2 % and 70.7 %, exceeding the maximum permissible levels.

Black-and-white breed bull calves were selected for the experiment considering age and live weight. Before the beginning of the experiment, all animals underwent clinical examination, were weighed, and baseline biochemical parameters and background levels of microelements were determined. Animals were fed individually according to balanced rations adjusted for live weight and age in accordance with established standards.

In stabilized blood, hemoglobin concentration, erythrocyte and leukocyte counts, and red blood cell indices were determined using a Mythic-18 hematology analyzer. Serum total protein concentration, protein fractions, and aminotransferase activity were assessed according to the method described by Vlislo (2012).

Data analysis was performed using Statistica 6.0 software (StatSoft Inc., USA). Data are presented as $\bar{x} \pm SD$ (mean \pm standard deviation). Differences between the control and experimental groups were evaluated using ANOVA, with differences considered statistically significant at $P < 0.05$, taking into account the Bonferroni correction.

Results and Discussion

Among the methods that allow an objective assessment of the level and direction of metabolic processes, evaluation of health status, and the course of physiological processes in the organism, blood analysis occupies a prominent place, since all mineral substances essential for life are delivered to cells via the blood, and its composition is a relatively stable indicator. The necessity of blood examination is primarily determined by the physiological significance of this tissue and the changes that occur in it under various pathological conditions.

Figure 1 presents the hematological and biochemical blood parameters of young cattle kept in different zones of technogenic load (AGC “Nyva” and AE “Ukraine”). The erythrocyte count in animals from AGC “Nyva” was slightly higher (5.4 ± 0.38 T/L) compared with young cattle from AE “Ukraine” (5.0 ± 0.22 T/L), which corresponds to a higher hemoglobin concentration (113 ± 0.68 g/L versus 105 ± 0.72 g/L, respectively). This may indicate a better state of erythropoiesis and oxygen-transport function of the blood in animals from AGC “Nyva”.

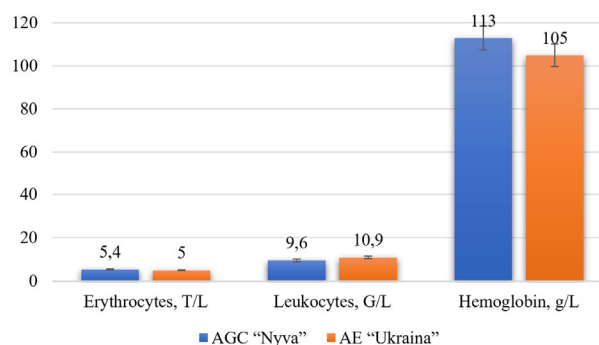


Fig. 1. Morphological blood parameters of young cattle reared in different zones of technogenic load, $\bar{x} \pm SD$

A decrease in erythrocyte count and hemoglobin concentration in the blood of young cattle from AE “Ukraina” compared with animals from AGC “Nyva” may indicate suppression of erythropoiesis and a reduction in the oxygen-transport function of the blood under conditions of increased technogenic load. Similar changes have been described in the literature as one of the early adaptive responses of the organism to prolonged exposure to environmental stressors, particularly heavy metals and industrial pollutants, which are capable of disrupting hemoglobin synthesis and the functional activity of the bone marrow.

The leukocyte count in the blood of young cattle from AE “Ukraina” was higher (10.9 ± 0.49 G/L) than in animals from AGC “Nyva” (9.6 ± 0.34 G/L). An increased leukocyte count may indicate immune system tension or an adaptive response of the organism to unfavorable environmental conditions.

The level of total protein in blood serum was higher in animals from AGC “Nyva” (64.0 ± 0.99 g/L) compared with AE “Ukraina” (60.25 ± 0.87 g/L). The proportion of albumins was also higher in the first group ($39.03 \pm 0.31\%$ versus $36.81 \pm 0.48\%$), indicating a better protein-synthesizing function of the liver and a more stable protein metabolism (Fig. 2).

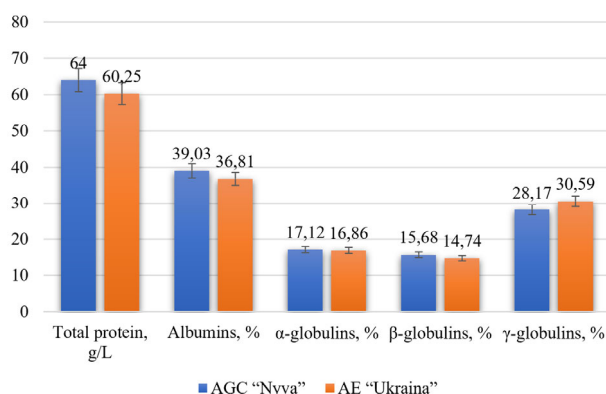


Fig. 2. Protein-synthesizing function of the liver in young cattle reared in different zones of technogenic load, $\bar{x} \pm SD$

The content of α - and β -globulins in animals from both farms did not differ significantly; however, the proportion of γ -globulins was higher in young cattle from AE “Ukraina” ($30.59 \pm 0.67\%$) compared with AGC “Nyva” ($28.17 \pm 0.75\%$). This may indicate activation of the humoral arm of the immune system under conditions of increased technogenic load.

Significant changes were observed in the activity of certain blood enzymes in bull calves from farms with different levels of technogenic load. In particular, in AE “Ukraina”, the activity of transaminases was higher by 9.1 % (AST) and 11.87 % (ALT) compared with AGC “Nyva” (Fig. 3). Increased aminotransferase activity (AST and ALT) in the blood of young cattle from AE “Ukraina” is an important indicator of the functional state of the liver and intensification of catabolic processes. The increase in the activity of these enzymes may be associated with increased permeability of hepatocyte cell membranes, activation of detoxification mechanisms, and the development of subclinical metabolic disorders under the

influence of technogenic factors. Such changes are considered markers of the initial stages of hepatodystrophic processes that are not accompanied by pronounced clinical manifestations.

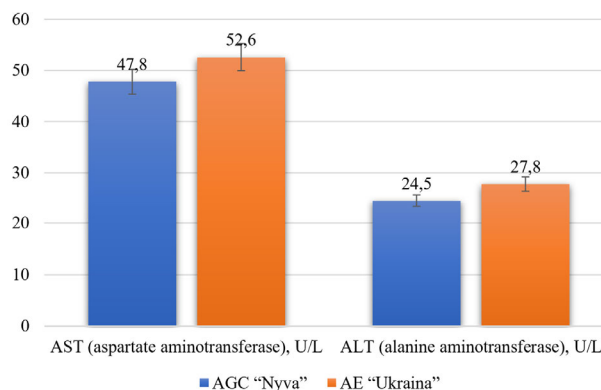


Fig. 3. Aminotransferase activity in the blood serum of young cattle reared in different zones of technogenic load, $\bar{x} \pm SD$

The obtained results indicate that young cattle kept in areas with higher technogenic load exhibit signs of immune system tension and increased enzymatic activity of the liver, whereas animals from less contaminated areas are characterized by more stable indicators of hematopoiesis and protein metabolism.

Thus, the combination of changes in morphological and biochemical blood parameters in young cattle kept under conditions of increased technogenic load indicates the formation of adaptive-compensatory responses manifested by immune system tension, disturbances in protein metabolism, and functional liver strain. At the same time, more stable blood parameters in animals from AGC “Nyva” indicate more favorable rearing conditions and a higher adaptive potential of the organism.

The obtained results emphasize the expediency of regular hematological and biochemical monitoring of young cattle under conditions of technogenic load in order to enable early detection of functional disorders and to substantiate preventive measures.

Conclusions

1. In young cattle kept in areas with increased technogenic load, a decrease in erythrocyte count, hemoglobin level, total protein, and albumin content was established, indicating suppression of hematopoiesis and disturbances in protein metabolism.
2. An increase in leukocyte count and the proportion of γ -globulins in the blood of animals from technogenically loaded areas indicates immune system tension and activation under environmental stress.
3. Increased AST and ALT activity in the blood of young cattle reared under conditions of increased technogenic load is an indicator of functional liver strain and intensification of metabolic processes.
4. The detected changes in morphological and biochemical blood parameters reflect the formation of adaptive-compensatory responses in young cattle depending on the level of technogenic load.

Conflict of interest

The authors declare no conflict of interest.

References

- Akter, M. T., Ferdous, K. A., Rahaman, T., Hassan, M. A., & Monjur, T. (2019). Exposure to environmental heavy metal (cadmium) through feed and its effect on bio-histomorphological changes in commercial quail. *Journal of Entomology and Zoology Studies*, 7, 965–971. URL: <https://www.entomoljournal.com/archives/2019/vol7issue5/PartP/7-4-333-341.pdf>.
- Bashchenko, M. I., Boiko, O. V., Honchar, O. F., Gutyj, B. V., Lesyk, Y. V., Ostapyuk, A. Y., Kovalchuk, I. I., & Leskiv, K. Y. (2020). The effect of milk thistle, meti-phen, and silimevit on the protein-synthesizing function of the liver of laying hens in experimental chronic cadmium toxicosis. *Ukrainian Journal of Ecology*, 10(6), 164–168. DOI: 10.15421/2020_276.
- Grymak, Y. I., Gutyj, B. V., Pryimych, V. I., Martyshuk, T. V., Kurylas, L. V., Kozenko, O. V., Dvyliuk, I. V., Magrelo, N. V., Vus, U. M., Vysotskyi, A. O., Krempa, N. Y., & Honcharov, O. L. (2025). Dynamics of immune system indicators in pregnant cows with physiological gestation and with endotoxiosis. *Scientific Messenger of LNU of Veterinary Medicine and Biotechnologies. Series: Agricultural Sciences*, 27(103), 195–200. DOI: 10.32718/nvlvet-a10322.
- Gul, I., Manzoor, M., Hashim, N., Shah, G.M., Waani, S.P.T., Shahid, M., Antoniadis, V., Rinklebe, J., & Arshad, M. (2021). Challenges in microbially and chelate-assisted phytoextraction of cadmium and lead – A review. *Environmental Pollution*, 287, 117667. DOI: 10.1016/j.envpol.2021.117667.
- Gutyi, B., Ostapiuk, A., Kachmar, N., Stadnytska, O., Sobolev, O., Binkevych, V., Petryshak, R., Petryshak, O., Kulyaba, O., Naumyuk, A., Nedashkivsky, V., Nedashkivska, N., Magrelo, N., Golodyuk, I., Nazaruk, N., & Binkevych, O. (2019). The effect of cadmium loading on protein synthesis function and functional state of laying hens' liver. *Ukrainian Journal of Ecology*, 9(3), 222–226. URL: <https://www.ujecology.com/articles/the-effect-of-cadmium-loading-on-protein-synthesis-function-and-functional-state-of-laying-hens-liver.pdf>.
- Gutyj, B. V., Hariv, I. I., Guta, Z. A., Leskiv, K. Y., Todoruk, V. B., Khymynets, P. S., & Martyshuk, T. V. (2023). The effect of cadmium on the immune status of young cattle and the effects of corrective factors. *Agrology*, 6(2), 45–48. DOI: 10.32819/021207.
- Gutyj, B. V., Martyshuk, T. V., Parchenko, V. V., Kaplaushenko, A. H., Bushueva, I. V., Hariv, I. I., Bilash, Y. P., Brygadyrenko, V. V., Turko, Y. I., & Radzykhovskiy, M. L. (2022). Effect of liposomal drug based on interferon and extract from *Silybum marianum* on antioxidative status of bulls against the background of contamination of fodders by cadmium and plumbum. *Regulatory Mechanisms in Biosystems*, 13(4), 419–425. DOI:10.15421/022255.
- Gutyj, B. V., Ostapyuk, A. Y., Sobolev, O. I., Vishchur, V. J., Gubash, O. P., Kurtyak, B. M., Kovalskyi, Y. V., Darmohray, L. M., Hunchak, A. V., Tsisaryk, O. Y., Shcherbatyy, A. R., Farionik, T. V., Savchuk, L. B., Palyadichuk, O. R., & Hrymak, K. (2019). Cadmium burden impact on morphological and biochemical blood indicators of poultry. *Ukrainian journal of Ecology*, 9(1), 235–239. URL: <https://www.ujecology.com/articles/cadmium-burden-impact-on-morphological-and-biochemical-blood-indicators-of-poultry.pdf>.
- Gutyj, B., Stybel, V., Darmohray, L., Lavryshyn, Y., Turko, I., Hachak, Y., Shcherbatyy, A., Bushueva, I., Parchenko, V., Kaplaushenko, A., & Krushelnytska, O. (2017). Prooxidant-antioxidant balance in the organism of bulls (young cattle) after using cadmium load. *Ukrainian Journal of Ecology*, 7(4), 589–596. URL: <https://www.ujecology.com/articles/prooxidantantioxidant-balance-in-the-organism-of-bulls-young-cattle-after-using-cadmium-load.pdf>.
- Kailasam, S., & Peiter, E. (2021). A path toward concurrent biofortification and cadmium mitigation in plant-based foods. *New Phytologist Foundation*, 232(1), 17–24. DOI: 10.1111/nph.17566.
- Kar, I., & Patra, A. K. (2021). Tissue Bioaccumulation and Toxicopathological Effects of Cadmium and Its Dietary Amelioration in Poultry—a Review. *Biological Trace Element Research*, 199(10), 3846–3868. DOI: 10.1007/s12011-020-02503-2.
- Kowalczyk, P., Sulejczak, D., Kleczkowska, P., Bukowska-Oško, I., Kucia, M., Popiel, M., Wietrak, E., Kramkowski, K., Wrzosek, K., & Kaczyńska, K. (2021). Mitochondrial Oxidative Stress—A Causative Factor and Therapeutic Target in Many Diseases. *International Journal of Molecular Sciences*, 22(24), 13384. DOI: 10.3390/ijms222413384.
- Kraikivska, H., Gutyj, B., Hunchak, A., Hunchak, V., Horalskyi, L., Sokulskyi, I., Martyshuk, T., Khariv, I., Slobodiuk, N., Demus, N., & Vus, U. (2023). Functional state and protein-synthesizing function of the liver of laying hens under conditions of cadmium loading. *Scientific Messenger of LNU of Veterinary Medicine and Biotechnologies. Series: Agricultural Sciences*, 25(99), 171–175. DOI: 10.32718/nvlvet-a9928.
- Lavryshyn, Y. Y., Gutyj, B. V., Leskiv, K. Y., Hariv, I. I., Yevtikh, L. H., & Shnaider, V. L. (2020). Influence of cadmium on the cellular part of the immune system of young cattle. *Ukrainian Journal of Veterinary and Agricultural Sciences*, 3(2), 47–52. DOI: 10.32718/ujvas3-2.08.
- Martyshuk, T. V., Gutyj, B. V., Zhelavskiy, M. M., Midyk, S. V., Fedorchenko, A. M., Todoruk, V. B., Nahirniak, T. B., Kisera, Ya. V., Sus, H. V., Chemerys, V. A., Lev-kivska, N. D., & Iglitskej, I. I. (2020). Effect of Butaselmavit-Plus on the immune system of piglets during and after weaning. *Ukrainian Journal of Ecology*, 10(2), 347–352. DOI: 10.15421/2020_106.
- 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), 2134. DOI: 10.31893/jabb.21034.
- Mylostyvyi, R., Sejian, V., Izhboldina, O., Kalinichenko, O., Karlova, L., Lesnovskay, O., Begma, N., Maren-

- kov, 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: 10.3390/ani11123391.
- Nordberg, M., & Nordberg, G. F. (2022). Metallothionein and Cadmium Toxicology-Historical Review and Commentary. *Biomolecules*, 12(3), 360. DOI: 10.3390/biom12030360.
- Ostapuyuk, A. O., Gutyj, B. V., Kozenko, O. V., Dvyluk, I. V., Shcherbatyi, A. R., Magrelo, N. V., Martyshuk, T. V., Klym, H. V., Krempa, N. Yu., Vus, U. M., Vysot-skyi, A. O. (2024). The influence of milk thistle, me-tifen and silimevit on the protein synthesis function of the liver of laying hens under cadmium load. *Scientific Messenger of Lviv National University of Veterinary Medicine and Biotechnologies. Series: Veterinary sciences*, 26(115), 57–63. DOI: 10.32718/nvlvet11508.
- Ostapuyuk, A. Y., Gutyj, B. V., Horalskyi, L. P., Mylostyvyi, R. V., Sokulskyi, I. M., Butsyak, A. A., Popadiuk, S. S., & Leskiv, Kh. Ya. (2023). Effect of milk thistle and silimevit on the functional state and protein synthesizing-function of the liver of laying hens under conditions of cadmium load. *Scientific Messenger of Lviv National University of Veterinary Medicine and Biotechnologies. Series: Veterinary sciences*, 25(112), 145–150. DOI: 10.32718/nvlvet11224.
- Ostapuyuk, A., Gutyj, B., Horalskyi, L., Sachuk, R., Todoriuk, V., Mylostyvyi, R., Sokulskyi, I., Vus, U., Kushnir, V., Kushnir, G., Martyshuk, T., Khariv, I., & Vozna, O. (2025). Effect of milk thistle (*Silybum marianum*) on the antioxidant status of laying hens under cadmium load. *Scientific Messenger of LNU of Veterinary Medicine and Biotechnologies. Series: Veterinary Sciences*, 27(118), 216–225. DOI: 10.32718/nvlvet11830.
- Ozturk, M., Metin, M., Altay, V., De Filippis, L., Ünal, B.T., Khursheed, A., Gul, A., Hasanuzzaman, M., Na-har, K., Kawano, T., & Caparrós, P. G. (2021). Molecular Biology of Cadmium Toxicity in *Saccharomyces cerevisiae*. *Biological Trace Element Research*, 199(12), 4832–4846. DOI: 10.1007/s12011-021-02584-7.
- Rezapour, M., Rezapour, H. A., Chegeni, M., & Khanjani, N. (2021). Exposure to cadmium and head and neck cancers: a meta-analysis of observational studies. *Reviews on Environmental Health*, 36(4), 577–584. DOI: 10.1515/reveh-2020-0109.
- Shchepentovska, O. M., & Kostyniuk, A. K. (2020). Histological and ultrastructural changes in turkey liver under intensive rear-ing and influence of xenobiotics. *Scientific Messenger of LNU of Veterinary Medicine and Biotechnologies. Series: Veterinary Sciences*, 22(99), 63–68. DOI: 10.32718/nvlvet9910.
- Shyntum, H. N., & Ushakova, G. A. (2015). Protective/detoxicative function of metallothionein in the rat brain and blood induced by controlled cadmium doses. *Visnyk Dnipropetrovskoho universytetu. Serii: Biologiya. Medytsyna*, 6(2), 103–107. DOI: 10.15421/021519.
- Slivinska, L. G., Shcherbatyy, A. R., Lukashchuk, B. O., Zinko, H. O., Gutyj, B. V., Lychuk, M. G., Chernushkin, B. O., Leno, M. I., Prystupa, O. I., Leskiv, K. Y., Slepokura, O. I., Sobolev, O. I., Shkromada, O. I., Kysterna, O. S., & Musiienko, O. V. (2019). Correction of indicators of erythrocytopoiesis and microelement blood levels in cows under conditions of technogenic pollution. *Ukrainian Journal of Ecology*, 9(2), 127–135. URL: <https://www.ujecology.com/articles/correction-of-indicators-of-erythrocytopoiesis-and-microelement-blood-levels-in-cows-under-conditions-of-technogenic-poll.pdf>.
- Slobodian, S. O., Gutyj, B. V., & Leskiv, K. Y. (2019). The level of lipid peroxidation products in the rats blood under prolonged cadmium and lead loading. *Ukrainian Journal of Veterinary and Agricultural Sciences*, 2(3), 15–18. DOI: 10.32718/ujvas2-3.04.
- Smychok, L., Gutyj, B., Sachuk, R., Khalak, V., Ilchyshyn, M., Vus, U., Stadnytska, O., Todoriuk, V., Martyshuk, T., Sobolta, A., Vysotskyi, A., & Magrelo, V. (2023). System of antioxidant protection of young cattle under cadmium load. *Scientific Messenger of LNU of Veterinary Medicine and Biotechnologies. Series: Agricultural Sciences*, 25(99), 182–189. DOI: 10.32718/nvlvet-a9930.
- Vlizlo, V. V., Fedoruk, R. S., & Ratysh, I.B. (2012). *Laboratorni metody doslidzhen u biolohiyi, tvarynyystvi ta veterynarniy medytsyni [Laboratory methods of investigation in biology, stock-breeding and veterinary]*. Dovidnyk. Reference book. Lviv. SPOLOM (in Ukrainian).
- Vus, U. M., Sachuk, R. M., Gutyj, B. V., Velesyk, T. A., Kozenko, O. V., Dvyluk, I. V., Magrelo, N. V., Klym, H. V., Vysotskyi, A. O., Krempa, N. Yu., & Martyshuk, T. V. (2025). Evaluation of the effectiveness of the drug Devivit Carnitine in the treatment of lactating cows with hepatodystrophy. *Scientific Messenger of Lviv National University of Veterinary Medicine and Biotechnologies. Series: Veterinary sciences*, 27(119), 3–8. DOI: 10.32718/nvlvet11901.
- Zeng, L., Zhou, J., Wang, X., Zhang, Y., Wang, M., & Su, P. (2021). Cadmium attenuates testosterone synthesis by promoting ferroptosis and blocking autophagosome-lysosome fusion. *Free Radical Biology and Medicine*, 176, 176–188. DOI: 10.1016/j.freeradbiomed.2021.09.028.
- Zhao, C., Yu, D., He, Z., Bao, L., Feng, L., Chen, L., Liu, Z., Hu, X., Zhang, N., Wang, T., & Fu, Y. (2021). Endoplasmic reticulum stress-mediated autophagy activation is involved in cadmium-induced ferroptosis of renal tubular epithelial cells. *Free Radical Biology and Medicine*, 175, 236–248. DOI: 10.1016/j.freeradbiomed.2021.09.008.
- Zheng, Y., Xiao, C., & Chi, R. (2021). Remediation of soil cadmium pollution by biomineralization using microbial-induced precipitation: a review. *World Journal of Microbiology and Biotechnology*, 37(12), 208. DOI: 10.1007/s11274-021-03176-2.