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Biochemical blood parameters in cattle exposed to radiation

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Abstract. Under contemporary conditions, the study of adaptive processes in living organisms remains highly relevant, particularly in relation to the biochemical blood parameters of cattle kept for extended periods in areas contaminated with radionuclides. This study aimed to determine blood biochemical parameters, analyse characteristic changes, assess their impact on animal health, and evaluate the degree of damage caused by radioactive iodine isotopes. The study examined biochemical parameters – including the activity of amylase, aspartate and alanine aminotransferases (AST and ALT), glutathione peroxidase (GPx), the concentration of lipid hydroperoxides (LHP), the level of ceruloplasmin, and total plasma protein – using standard biochemical methods. The results revealed a wide range of parameter values; however, no significant differences were observed between the groups of cattle exposed to various doses of ionising radiation (1 Gy to the body, 2 Gy to the gastrointestinal tract, and up to 40 Gy to the thyroid gland) resulting from Chornobyl radioactive fallout, including radioactive iodine affecting the thyroid and those kept in relatively uncontaminated areas exposed to only minimal doses of radiation (within a few mGy). Characteristic changes in biochemical parameters and potential alterations in health status were analysed. It was established that under conditions of high-dose thyroid irradiation (40 Gy to the thyroid gland), powerful adaptive mechanisms are activated in the body. These mechanisms counteract the harmful effects of ionising radiation at the organismal level and help preserve important productive traits such as fertility and productivity. These findings may serve as a basis for developing a system of measures aimed at regulating the adaptive responses of organisms exposed to ecopathogenic factors

Keywords: stable iodine (^{127}I); radioactive iodine (^{131}I); radionuclide-contaminated area; thyroid gland; blood; enzymatic activity; biochemical parameters

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INTRODUCTION

The vast scale of radionuclide contamination in Ukraine following the Chornobyl nuclear power plant (ChNPP) accident led to the exposure of the country's population and livestock to radiation. This prompted scientists to study various aspects and consequences of ionising radiation's impact on people and other biological entities. A clear consequence of the Chornobyl radioactive fallout on human health was the increase in thyroid gland pathologies within the first five years after the accident. This was largely due to cows' milk being contaminated with radioactive iodine isotopes. While medical issues related to radioactive iodine exposure in humans have received significant attention from scientists worldwide, the biological effects of radioactive iodine isotopes on livestock have been comparatively understudied. Therefore, research into the molecular mechanisms of ionising radiation on animals and the development of radiation-induced adaptive processes for living organisms to withstand chronic ionising radiation exposure remains highly relevant. Crucial studies on the aftermath of the mentioned accident, particularly examining the patterns of radionuclide transfer through trophic chains from soil to food products, have been conducted in Ukraine, Germany, and England (von Zallinger & Tempel, 1988). These studies highlight the ongoing relevance of the Chornobyl radionuclides' impact, even 30 years after the accident (Mushawwir *et al.*, 2020).

The research results presented in this article, focusing on cattle under production conditions and the artificial introduction of radioactive iodine, logically extend the experiments of M.M. Lazarev & A.V. Klepko (2023). Their study assessed the haematological blood parameters of cattle experiencing "iodine" pathology observed post-Chornobyl accident. That study analysed data on ^{127}I content in the Ukrainian Polissia region, an area with radioactive contamination, and examined the health consequences for cattle due to insufficient natural stable iodine, including characteristic physiological changes. M. Haque *et al.* (2024) highlight that the Polissia region is characterised by a deficiency in biogenic microelements, particularly iodine, due to the region's specific soil and climatic conditions. These authors emphasise that low iodine levels in the soil directly affect its concentration in plants and, consequently, in the organisms that consume these plants as feed. This creates a predisposition for iodine deficiency conditions in both animals and humans residing in this region.

O. Pareniuk & N. Yasuda (2021) emphasised that radioactive iodine is a key factor in damaging biological systems following nuclear accidents. This is because it rapidly integrates into biological cycles, particularly in the thyroid gland, leading to acute and chronic radiation effects. They highlight that during the Chornobyl accident, the ^{131}I isotope was the primary source of population exposure in the initial weeks after the explosion. This isotope accumulates in humans and animals through the inhalation of radioactive aerosols and the consumption of contaminated food products. M. Bartusková *et al.* (2023) described the diagnostic signs and clinical picture of radioactive iodine-induced radiation damage in animals. However, they did not adequately address cases where animal populations affected by ^{131}I were in regions endemic for stable iodine deficiency.

M.M. Talerko *et al.* (2020) noted in their research that ^{127}I deficiency in cattle leads to stunted growth, low body weight, reduced productivity, and characteristic changes in the hair coat, such as curliness and excessive hair length. Similar health deviations in cattle were observed in radioactively contaminated areas during the acute phase of the Chornobyl accident (Labunska *et al.*, 2021). D. Horikami *et al.* (2022) investigated the impact of ^{131}I on the thyroid gland of cattle following the Fukushima nuclear accident. They confirmed that thyroid gland damage leads to systemic changes, including bradycardia, rumen hypotonia, impaired erythropoiesis and leukopoiesis, and reduced reproductive functions. M.M. Lazarev & A.V. Klepko (2023), in their experimental studies, corroborated that the artificial introduction of ^{131}I into the cattle's body causes pathological changes similar to those observed with stable iodine deficiency. Thus, research results indicate a close relationship between physiological disturbances in animals and iodine deficiency, regardless of whether it is radioactive or stable.

Consequently, determining both haematological and biochemical blood parameters can not only characterise the health status of animals but also provide a basis for assessing the extent of radioactive iodine isotope damage to the body. This can then be used to develop a system of measures to regulate the body's adaptive mechanisms when exposed to ecopathogenic factors. Therefore, this study aimed to investigate the biochemical blood parameters that characterise the key parameters of the physiological state of cattle in iodine-deficient and radionuclide-contaminated areas.

MATERIALS AND METHODS

The study was conducted on two groups of Black-and-White cows, with 25 heads in each group, in their 3rd to 5th lactation periods under production conditions. The first group of animals was evacuated from the exclusion zone (village of Volodymyrivka, Poliske District, Kyiv Region) three weeks after the Chornobyl accident, which occurred on 26 April 1986. At the time of the accident, the animals were kept on pasture. The first group of cows was formed from a herd that was evacuated from the village of Volodymyrivka. These cows were transferred to a farm located in the urban-type settlement of Poliske, Kyiv Region, where the radioactive contamination density was more than 20 times lower than in the village of Volodymyrivka. This difference in radioactive contamination density led to a significant difference in the radiation doses received by the animals' bodies as a whole and specifically by the cows' thyroid glands.

This study was based on the conclusions and data obtained in the research of N.A. Beresford *et al*. (2000), which formed the basis for further analysis. The observation of the cows and their offspring was conducted from 1987 to 1995. This research presents the results of biochemical status studies of the cows for the year 1989.

Cows from a farm whose territory was not considered radioactively contaminated according to the Law of Ukraine No. 791a-XII (1991) were used as a control group. The animals were kept under identical conditions on a standard farm diet but were exposed to varying doses of ionising radiation to the thyroid gland (TG). The first group of cows received 40 Gy of radioactive ^{131}I radiation to the TG, and the second group received 10 Gy. The study assessed the overall clinical condition of the animals, recorded cow productivity (using the control milking method before the start of the experiment and monthly thereafter), haematological parameters (Lazarev & Klepko, 2023), thyroid hormone levels using radioimmunoassay in test systems for thyroxine (T4RIA-Pg) and triiodothyronine (T3-RIA-Pg), and a range of biochemical parameters. These parameters showed a characteristic dependence of the observed changes on the thyroid gland radiation doses and on the keeping conditions, particularly related to the deficiency of biogenic microelements in the animals' diets. For biochemical (as well as haematological) studies, cattle blood treated with the anticoagulant heparin was used, and collected from 5–6 animals in each group.

To evaluate the biochemical profile in the animals' blood plasma, the activity of enzymes (amylase, aspartate and alanine aminotransferases (AST, ALT), glutathione peroxidase (GP)), as well as the levels of ceruloplasmin, total protein, cholesterol, sialic acids, lipid hydroperoxides (LPO), and thyroid hormones (T_3 and T_4) were determined. The studies were conducted using methods described in L.I. Ostapchenko *et al*. (2019), and the results were compared with the normative values provided in V.V. Vlizlo *et al*. (2012). Statistical analysis was performed using methods of variational statistics (Hruzieva *et al*., 2020).

RESULTS AND DISCUSSION

Given that radioactive iodine was the primary factor in radiation damage to livestock, the functional activity of the thyroid gland was assessed by measuring thyroid hormone levels in blood plasma (Giovanella *et al*., 2022; Lazarev *et al*., 2024). Comparing the hormonal status of animals in the first group, which experienced the greatest radiation exposure (40 Gy to the TG and approximately 1 Gy to the whole body), with those in the second group (10 Gy to the TG) revealed a trend towards decreased concentrations of thyroid hormones (T_3 and T_4) in the blood of animals exposed to higher doses of thyroid radiation. However, in both groups, thyroid hormone levels were below the physiological norm (Table 1). The physiological range of T_4 and T_3 concentrations in cow blood varies throughout the year: before calving, it is 46-90 nmol/L and 1.2-1.6 nmol/L; at the beginning of lactation, 43-125 nmol/L and 2.0-6.0 nmol/L; at peak lactation, 57-103 nmol/L and 2.3-3.5 nmol/L; and at the end of lactation, 43-86 nmol/L and 2.4-3.2 nmol/L.

Table 1. Thyroid hormone levels in blood plasma of experimental cows (nmol/L)

Cow groups	Parameter	Time of assessment, months after ^{131}I exposure					
		6	8	10	13	15	20
1	T_3	0.33 ± 0.05	0.47 ± 0.1	0.49 ± 0.01	0.69 ± 0.06	1.4 ± 0.5	0.96 ± 0.2
2	T_3	0.43 ± 0.03*	0.53 ± 0.07	0.51 ± 0.07	0.61 ± 0.04	1.37 ± 0.04	1.0 ± 0.03
1	T_4	27.7 ± 3.3	29.5 ± 6.4	43.1 ± 4.7*	44.3 ± 3.6	63.7 ± 4.8	38.0 ± 3.8*
2	T_4	29.6 ± 1.2	30.1 ± 2.7	34.6 ± 1.8	46.1 ± 0.8	61.5 ± 4.3	44.5 ± 3.8

Note: ^{131}I – radioactive iodine, T_3 – triiodothyronine, and T_4 – thyroxine, * – $p < 0.05$
Source: developed by the authors

The analysis of thyroid hormone levels in the blood plasma of the experimental cows indicates that the hormone levels in cows from groups 1 and 2 fluctuate with a nearly identical pattern. However, a significant difference in triiodothyronine levels is observed six months after radioactive iodine exposure, and in thyroxine levels, at 10- and 20-months post-exposure.

Thyroid hormones (T_3 and T_4) are synthesised in the follicular cells of the thyroid gland (Fig. 1) by attaching iodine to the residues of the amino acid tyrosine, which is a component of thyroglobulin (TG), a soluble glycoprotein (660 kDa). The daily secretion of T_4 by the thyroid gland is 80–100 µg, and that of T_3 is approximately 5 µg. T_3 is significantly more active, making a substantial portion of T_4 a precursor to T_3. While some triiodothyronine is synthesised in the thyroid gland, it is also produced in peripheral body cells through the monodeiodination of thyroxine, catalysed by the enzyme 5'-monodeiodinase (requiring the trace element selenium). Consequently, T_3 levels in serum or plasma do not always accurately reflect thyroid gland dysfunction.

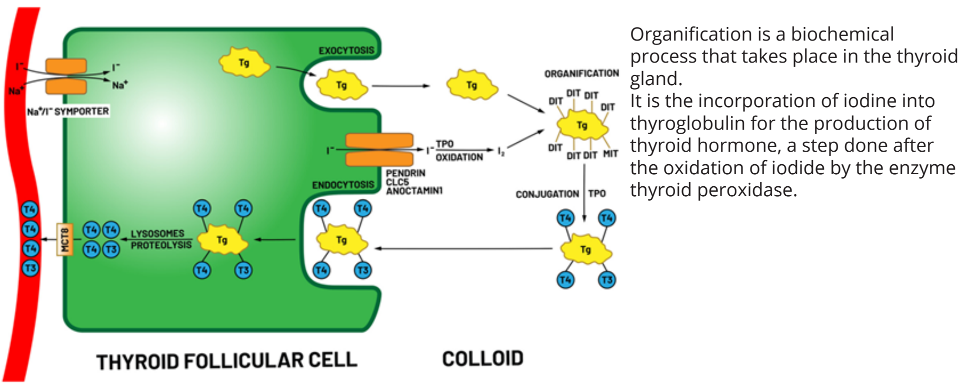

Figure 1. Thyroid hormone production

Note: T_3 – triiodothyronine; T_4 – thyroxine; Tg –thyroglobulin; TPO – thyroid peroxidase; MIT – monoiodotyrosine; DIT – diiodotyrosines; CLC5 – chloride channel 5; Na^+/I^- symporter; pendrin; anoctamin1; MCT8 – monocarboxylate transporter 8
Source: L. Giovanella *et al.* (2022)

Through the action of proteases and peptidases in the lysosomes of follicular cells, Tg is broken down, and T_3 and T_4 are secreted into the blood, where they bind to plasma proteins. T_4 has a high affinity for globulin (thyroxine-binding globulin – TBG), a lower affinity for prealbumin, and a very weak affinity for albumin (approximately 75% binds to TBG and 15%–20% to prealbumin and albumin, respectively). Only 0.5% of T_4 remains in a free (unbound) state. T_3 binds almost exclusively to TBG, with its free fraction accounting for 0.05%. The biological half-life of T_4 is 7-9 days, and that of T_3 is 2 days. Both bound and free forms of the hormones exist in dynamic equilibrium. Free forms of triiodothyronine penetrate cell membranes relatively easily, influencing all types of metabolism.

T_4 and T_3 levels increase in the blood during hyperthyroidism, while a decrease in T_3 and T_4 levels can be observed in hypothyroidism, liver diseases, kidney diseases, lipomobilisation syndrome, ketosis, sepsis, pneumonia, peritonitis, malignant tumours, and also with the administration of iodine preparations, corticosteroids, certain antibiotics and sulfonamides, and heparin. This is why liver dysfunction can be one of the factors contributing to changes in the cows' condition, as evidenced by the data presented in Table 1.

Biochemical blood analysis, a key method of laboratory diagnosis, is used to study the function of internal organs and their systems, including metabolic processes occurring in the body. In environments contaminated with substances harmful to animal health, particularly radioactive substances, pathological changes are primarily observed in the liver – a natural barrier against toxic substances (ICRP Publication…, 2023). Deviations in liver function are indicated by altered activity levels of enzymes such as ALT, AST, and bilirubin, while kidney pathology is indicated by an increase or decrease in creatinine and urea levels in the blood. The dysfunction of organs and their systems also leads to inflammatory processes, which are indicated by changes in C-reactive protein and sialic acid levels (Vlizlo *et al.*, 2012). In addition to these parameters, other markers (over 500 substances) are studied to assess the physiological state of the organism. The analysis of the aforementioned enzyme activities and substance levels reveals whether the chemical reactions of metabolic processes are proceeding normally or with deviations.

Biochemical analysis can indicate the development of diabetes mellitus in cases of elevated blood glucose levels, suggest myocardial infarction or hepatitis with changes in aminotransferase activity, and point to atherosclerosis and cardiovascular diseases with increased cholesterol levels. Liver dysfunction and bile flow obstruction are indicated by changes in bilirubin levels; kidney function abnormalities are suggested by elevated or decreased creatinine and urea levels; severe pathological changes are reflected in changes in total protein levels; and pancreatitis is indicated by increased amylase activity (Ostapchenko *et al.*, 2019).

A definitive diagnosis is confirmed by analysing specific biochemical blood parameters, considering their changes in the context of the mentioned deviations, which affect the overall physiological state of the organism and the metabolic processes of tissue cells in internal organs. These changes are reflected in the characteristic variations of the biochemical parameters presented above. Tables 2 and 3 present the results of biochemical parameter analysis, demonstrating diverse deviations influenced by the time of year and varying levels of thyroid gland radiation in cows. Blood from cows not exposed to radioactive iodine is used as a control.

Table 2. Enzyme activity in cow blood with varying levels of TG radiation

Enzymes, units of activity → / Animal groups↓	Amylase, mg/hour · mL	AST, μmol/hour · mL	ALT, μmol/hour · mL	GP, μmol glutathione/min
March				
1	137.7 ± 16.0	1.6 ± 0.08*	1.3 ± 0.2	0.87 ± 0.13*
2	105.7 ± 22.0	1.13 ± 0.05*	0.78 ± 0.09	10.0 ± 0.1*
Control	125.1 ± 17.8	3.65 ± 0.07	1.04 ± 0.03	0
July				
1	66.5 ± 9,2*	0.8 ± 0.06*	0.21 ± 0.03	7.2 ± 0.2
2	46.2 ± 9.0	0.8 ± 0.06*	0.3 ± 0.04	8.2 ± 0.06
Control	40.0 ± 5.2	0.3 ± 0.03	0.06 ± 0.01	6.7 ± 0.08

Note: * – $p < 0.05$; significant difference between experimental and control groups; enzyme activity: amylase, aspartate aminotransferase (AST), alanine aminotransferase (ALT), glutathione peroxidase (GP)
Source: developed by the authors

Table 3. Levels of selected biochemical parameters in cow blood with varying levels of TG radiation

Content → Animal groups↓	Ceruloplasmin, мg%	Cholesterol, мg%	Sialic acids, mmol/L	Protein, mg/mL	LPO, arb. unit
March					
1	18.0 ± 3.0	112.0 ± 9.7	141 ± 4.6*	131.8 ± 7.5*	0.15 ± 0.04
2	20.2 ± 1.3	82.5 ± 10.4*	183.0 ± 9.5*	115.0 ± 7.3*	0.3 ± 0.08
Control	22.2 ± 1.05	147.8 ± 8.0	236.0 ± 3.3	90.5 ± 3.3	0.43 ± 0.07
July					
1	24.5 ± 1,2*	235.0 ± 8.8	150.0 ± 11.4	114.6 ± 5.7	1.5 ± 0.07*
2	24.2 ± 3.4*	254.0 ± 23.2	136.0 ± 10.8	11.6 ± 8.4	1.3 ± 0.07
Control	6.5 ± 0.3	212.0 ± 16.0	145.0 ± 9.3	97.9 ± 3.8	1.26 ± 0.07

Note: * – $p < 0.05$; in cattle blood, ceruloplasmin levels are 25.0–36.0 mg%; concentration of ceruloplasmin, total protein, cholesterol, sialic acids, and lipid hydroperoxides (LPO; arb. unit – arbitrary units)
Source: developed by the authors

As clearly seen from the results presented in Table 2, the activity of the studied enzymes varies not only under the influence of radioactive iodine but also shows a pronounced influence of feeding conditions during the summer and spring periods. The AST and ALT activity data in cow blood are within the normal range or lower. Seasonal changes in these parameters are particularly noticeable: in July, the activity of these enzymes in the blood of both the experimental and control groups is lower than in March and below the normal range (as shown below). In some cases, reduced AST activity can indicate pathological conditions: liver rupture, severe necrotic damage, and chronic vitamin B6 deficiency. It is difficult to conclude liver damage as other evidence is needed. A rapid decrease in ALT activity with a simultaneous significant increase in bilirubin and an increase in prothrombin time indicates a poor prognosis and suggests severe necrotic changes in liver tissue. However, without information on the latter two parameters, only predictions can be made, which should be considered in future studies.

AST (48-108 U/L or 2.8-6.5 μmol/(hour · mL), or 0.80-1.80 μmol/s · L) and ALT (17-40 U/L or 1.02-2.39 μmol/(hour · mL), or 0.28-0.67 μmol/s · L) represent the activity of enzymes in cattle blood (Vlizlo *et al.*, 2012; Ostapchenko *et al.*, 2019). These enzymes, located in the cells of most organs and systems, transfer amino groups from aspartic acid and alanine to alpha-ketoglutaric acid. Since aminotransferases are not specific tests for evaluating the condition of individual organs, the site of enzyme release into the blood is determined. They exhibit high activity in the cytoplasm of cells (AST also in mitochondria), and even minor tissue damage increases their activity in serum (plasma). The determination of AST and ALT activity in blood serum is performed for the diagnosis of liver diseases (hepatitis, hepatosis, etc.). AST activity is determined in the blood serum of cattle and horses, while both AST and ALT are determined in the blood serum of pigs, dogs, and cats, which depends on the degree of activity of these enzymes in the hepatocytes of different animal species. This is because the cells of large and small animals exhibit correspondingly high AST and ALT activity.

A comprehensive assessment of animal health involves the dynamic study of the most common biochemical blood parameters, which characterise the functional activity of metabolic processes in the body as a whole and in its individual organs. Table 3 presents the parameters for assessing the state of metabolic processes in the bodies of cows exposed to varying doses of thyroid gland radiation from radioactive iodine exposure. The primary focus was on biochemical parameters that monitor the pro- and antioxidant activity of cattle blood plasma and the activity of specific metabolites responsible for the functional state of individual organs, particularly the liver and other hepato-associated deviations. Biochemical blood parameters are quite labile parameters of the biochemical state and can fluctuate within a wide range depending on environmental conditions and animal husbandry practices. Logically, it was hypothesised that the additional impact of ionising radiation on the thyroid gland could cause significant changes in the biochemical state of the experimental animals' bodies.

The results of the biochemical studies confirm the understanding of many researchers regarding the significant compensatory capabilities of organisms' biochemical status and the strain on certain biochemical parameters during unfavourable times of the year, particularly spring. This is when a significant deviation of blood parameters in experimental animals from the control group is observed. It should be noted that the impact of radiation is less pronounced than the influence of animal husbandry conditions. Amylase activity (g/hour · L) in cows of group 1 (which received a higher dose of TG radiation) was similar to the control, while the values for animals in group 2 (with a 4-fold lower radiation dose) were lower in the spring period (March). Amylolytic activity for all three groups of cows in March was higher than in July, which was likely primarily due to the cows' diet in the spring and summer periods. It should be noted that animals fed with high-starch feeds have higher amylolytic activity than those fed with low-starch feeds. Researchers H. Yang *et al*. (2012) noted that the activity of bacterial amylolytic enzymes is influenced by certain amino acids. Methionine at a concentration of 1-2 mg/mL stimulates, while lysine inhibits bacterial amylase activity and growth.

In cattle blood, the ceruloplasmin content is 25.0-36.0 mg%, as per the normal range specified in the study by V.V. Vlizlo *et al*. (2012). The relative ceruloplasmin content in the blood of animals in the experimental groups was slightly below this normal range, regardless of the TG radiation dose (except for the control group in July). Ceruloplasmin, mg%, is a key factor in neuroendocrine regulation and the body's natural defence against stress, inflammation, allergic reactions, and other diseases. This protein is a Cu-containing glycoprotein that belongs to the acutephase proteins. It participates in iron metabolism and haematopoiesis and acts as an antioxidant. It has oxidase activity, which allows it to break down biogenic amines and other substrates, thus playing a role in neuroendocrine regulation. Changes in ceruloplasmin activity usually correlate with changes in copper ions. A sharp disturbance in copper metabolism is observed in anaemia, where its concentration in the blood significantly increases due to a decrease in deionised copper content in liver tissue.

The reference values for total cholesterol in blood serum, according to V.V. Vlizlo *et al*. (2012), range from 2.3-6.6 mmol/L or 88.93-255.189 mg%. Generally, cholesterol levels in all groups (experimental and control) fall within these reference values. Elevated cholesterol concentrations are observed in liver diseases with impaired bile acid formation (hepatitis) and bile secretion (cholestasis), lipoid nephrosis, renal failure, ketosis, hypothyroidism, and excessive carbohydrate and fat consumption by animals. Hypocholesterolaemia occurs with prolonged deficiencies in dietary fats and carbohydrates, as well as in hyperthyroidism and liver diseases.

Researchers L.I. Ostapchenko *et al*. (2019) observed a decrease in cholesterol content (mg%) in spring and an increase in summer. They noted that cholesterol is a steroid synthesised mainly in the liver and also enters the blood from the intestine. Cholesterol in the blood exists in free and bound forms. Its content in blood serum depends on liver function. M.C. Bell (1985) indicated that elevated cholesterol concentrations (hypercholesterolemia) are observed in hyperlipidaemia, increased serum triacylglycerol levels in liver diseases with impaired bile acid formation (hepatitis, hepatodystrophy) and bile secretion (cholestasis), glomerulonephritis, lipoid nephrosis, chronic renal failure, pancreatic tumours, ketosis, diabetes mellitus, hypothyroidism, gout, and excessive carbohydrate and fat consumption by animals.

S. Pegolo *et al*. (2023) noted that a decrease in serum cholesterol concentration, particularly its esterified fraction (hypocholesterolaemia), is observed in hepatitis, hepatodystrophy, and cirrhosis due to the impaired synthetic function of hepatocytes, deficiencies in dietary fats and carbohydrates, and reduced lipoprotein synthesis. They also emphasised that in hyperthyroidism, energy metabolism is increased, leading to higher cholesterol consumption and, consequently, its reduction in blood serum. Thus, changes in cholesterol levels can be important markers of liver and endocrine metabolic disorders.

S.M. Razavi *et al*. (2023) indicated that sialic acids are important components of glycoconjugates and play a key role in cellular processes, including immune response, inflammation, and intercellular interaction regulation. The observed trend of decreased sialic acid levels in the experimental animal groups compared to the control may result from degenerative processes in the central nervous system associated with impaired biosynthesis of carbohydrateprotein complexes. Furthermore, S.M. Razavi *et al*. (2023) and V. Kassich *et al*. (2021) highlighted that changes in sialic acid concentration can indicate acutephase inflammatory response disorders occurring in various pathological conditions, including infectious and parasitic diseases. The authors also emphasised the significance of sialic acids as potential biomarkers for neurodegenerative and metabolic disorders in animals, which aligns with other studies establishing their role in the pathogenesis of several systemic diseases.

Protein (mg/mL) in cattle blood primarily demonstrates hyperproteinaemia in the experimental animal groups compared to the control, although there is an isolated case of hypoproteinaemia in group 2 in July. Based on the analysis of these parameters and considering general information on protein metabolism (Koch *et al*., 2023), it can be inferred that hypoproteinaemia arose from prolonged malnutrition, alimentary osteodystrophy, hypokobaltosis, chronic gastrointestinal disorders, nephritis and nephrosis, liver cirrhosis, or tuberculosis. Conversely, hyperproteinaemia occurs due to protein overfeeding, ketosis, secondary osteodystrophy, toxicosis, liver dystrophy and inflammation, or severe forms of diarrhoea, dehydration, or acute inflammatory processes.

T. Liu *et al*. (2020) indicated that glutathione peroxidase (GPx or GP, μmol glutathione/min·mg protein) activity data suggest that biochemical processes tend to stabilise during the summer. As highlighted by S. Diyabalanage *et al*. (2020), GP is a selenoprotein found in the cytosol (70%) and mitochondria (20%-30%). The enzyme's highest activity is in the liver, lens, adrenal glands, erythrocytes, and pancreas, while the lowest is in muscles, the gastrointestinal tract, testes, and connective tissue. The enzyme protects erythrocytes from methaemoglobin formation, premature ageing, and haemolysis, and neutrophils and macrophages during the "respiratory burst". Inducers of the enzyme include selenium ions (which are part of the enzyme's active site), copper, vitamins A, E, C, B2, female sex hormones, and catecholamines. GP is activated in the initial stages of stress, vitamin E deficiency, exposure to ionising radiation, and the consumption of alcohol and fatty foods. GP activity is high in the mother's liver and lungs, placenta, and foetal liver.

The concentration of lipid hydroperoxides (LPO, arbitrary unit) remains within control values, as the excessive intake and consumption of oxygen, characteristic of all types of stress, leads to an increase in primary molecular products of lipid peroxidation (LPO), particularly lipid hydroperoxides. Researchers S. Diyabalanage *et al*. (2020) emphasise that most LPO is formed from polyunsaturated fatty acids and total lipids, and their synthesis occurs in significantly larger quantities than the synthesis of malondialdehyde (MDA), although they decompose rapidly. The maximum concentration of LPO can only be determined at the initial stage of the reaction. LPO levels are high in old age and increase with physical exertion. LPO increases intracellular calcium concentration, which is associated with glutathione oxidation.

From the analysis of biochemical parameters such as AST and ALT, ceruloplasmin concentration, total protein, cholesterol, sialic acids, GP, and LPO, it can be concluded that the observed deviations indicate impaired functioning of the body as a whole and its organs, particularly the liver, which is involved in detoxification processes. These deviations are the result of the formation of possible adaptive mechanisms in response to ionising radiation and other exogenous factors and require additional attention and study.

CONCLUSIONS

The studies conducted on the levels of thyroid hormones triiodothyronine (T_3) and thyroxine (T_4), and biochemical blood parameters in cows exposed to radioactive iodine, which resulted in varying doses of thyroid gland radiation (40 and 10 Gray), showed that, unlike haematological parameters, these blood parameters are less informative in terms of assessing their radiosensitivity.

The analysis of T_3 and T_4 levels in the blood plasma of the experimental cows demonstrated that their levels in animals of groups 1 and 2 fluctuated with a nearly identical pattern. However, a significant difference in triiodothyronine levels was observed six months after radioactive iodine exposure (0.43 ± 0.03* nmol/L; $p < 0.05$), and in thyroxine levels, at 10- and 20-months postexposure (43.1 ± 4.7* and 38.0 ± 3.8* nmol/L, respectively; $p < 0.05$). This is considering the physiological ranges of T_3 and T_4 concentrations in cow blood, which vary throughout the year: before calving, 1.2-1.6 and 46-90 nmol/L; at the beginning of lactation, 2.0-6.0 and 43-125 nmol/L; at peak lactation, 2.3-3.5 and 57-103 nmol/L; and the end of lactation, 2.4-3.2 and 43-86 nmol/L. At 20 months post-radioactive iodine exposure decreased T_3 and T_4 levels in the blood were observed in hypothyroidism and liver dysfunction, which may be contributing factors to changes in the cows' condition.

The studied individual biochemical parameters (enzyme activities of amylase, aspartate and alanine aminotransferase, glutathione peroxidase, lipid hydroperoxide content, ceruloplasmin, and total protein levels in the plasma of cattle) fluctuate within wide ranges. However, they do not always significantly and consistently differ between groups of animals that have been exposed to different doses of thyroid gland irradiation and those that have not received significant doses of irradiation (at levels of a few mGy) to this important organ. A notable example is the activity of aspartate aminotransferase in the blood of groups 1 and 2 of cows, exposed to different doses of ^{131}I thyroid irradiation (40 and 10 Gy, respectively), as well as the control animals in spring and summer, which were within the normal range (2.8-6.5 μmol/hour · mL) or lower (in March – 1.6 ± 0.08*; 1.13 ± 0.05*; 3.65 ± 0.07, and in July – 0.8 ± 0.06*; 0.8 ± 0.06*; 0.3 ± 0.03 μmol/hour · mL, $p < 0.05$)

The obtained results indicate that even under conditions of high-dose thyroid gland radiation (40 Gy to the TG, which would be absolutely lethal if applied to the whole animal), the body activates powerful compensatory (adaptive) mechanisms. These mechanisms allow for the neutralisation of the negative effects of ionising radiation at the organism level and the preservation of crucial agricultural traits such as reproduction and productivity. Research into changes in the body's antioxidant defence system and the assessment of oxidative stress levels under chronic radiation exposure is promising. Furthermore, the identification of specific biomarkers that can serve as early indicators of radiation damage in cattle is crucial.

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CONFLICT OF INTEREST

None.

REFERENCES

[1] Bartusková, M., Selivanova, A., Malátová I., Hůlka J., Škrkal, J., Rosmus, J., Kapyltsova, A., & Rulík, P. (2023). A comparison of different detection techniques for ^{137}Cs measurements of cattle *in vivo*. *Radiation Protection Dosimetry*, 199(19), 2373-2382. doi: 10.1093/rpd/ncad252.

[2] Bell, M.C. (1985). Radiation effects on livestock: Physiological effects, dose response. *Veterinary and human toxicology,* 27(3), 200-207.

[3] Beresford, N.A., *et al*., (2000). The transfer of ^{137}Cs and ^{90}Sr to dairy cattle fed fresh herbage collected 3.5 km from the Chernobyl nuclear power plant. *Journal of Environmental Radioactivity,* 47(2), 157-170. doi: 10.1016/s0265-931x(99)00037-5.

[4] Diyabalanage, S., Dangolla, A., Mallawa, C., Rajapakse, S., & Chandrajith, R. (2020). Bioavailability of selenium (Se) in cattle population in Sri Lanka based on qualitative determination of glutathione peroxidase (GSH-Px) activities. *Environmental Geochemistry and Health*, 42(2), 617-624. doi: 10.1007/s10653-019-00395-3.

[5] Giovanella, L., Avram, A.M., Ovčariček, P.P., & Clerc, J. (2022). Thyroid functional and molecular imaging. *Medical Functional Imaging*, 51(2), article number 104116. doi: 10.1016/j.lpm.2022.104116.

[6] Haque, M., Binte Dayem, S., Tabassum Tasnim, N., Islam, M.R., & Shakil, M.S. (2024). Biological impact of Chornobyl radiation: A review of recent progress. *International Journal of Radiation Biology*, 100(10), 1405-1415. doi: 10.1080/09553002.2024.2391813.

[7] Horikami, D., *et al*. (2022). The effect of exposure on cattle thyroid after the Fukushima Daiichi nuclear power plant accident. *Scientific Reports*, 12, article number 21754. doi: 10.1038/s41598-022-25269-0.

[8] Hruzieva, T.S., *et al*. (2020). *Biostatistics*. Vinnytsia: Nova Knyga.
[9] ICRP Publication 153: Radiological Protection in Veterinary Practice. (2023). *Annals of the ICRP*, 51(4), (9-95). doi: 10.1177/01466453221142702.
[10] Kassich, V., Kasianenko, O., Zazharskyi, V., Yatsenko, I., & Klishchova, Zh. (2021). Influence of ionizing radiation on the allergic reactivity of tuberculosis-infected laboratory animals. *Scientific Horizons*, 24(10), 17-27. https://doi.org/10.48077/scihor.24(10).2021.17-27.
[11] Koch, F., Otten, W., Sauerwein, H., Reyer, H., & Kuhla, B. (2023). Mild heat stress-induced adaptive immune response in blood mononuclear cells and leukocytes from mesenteric lymph nodes of primiparous lactating Holstein cows. *Journal of Dairy Science*, 106(4), 3008-3022. doi: 10.3168/jds.2022-22520.
[12] Labunska, I., Levchuk, S., Kashparov, V., Holiaka, D., Yoschenko, L., Santillo, D., Johnston, P. (2021). Current radiological situation in areas of Ukraine contaminated by the Chornobyl accident: Part 2. Strontium-90 transfer to culinary grains and forest woods from soils of Ivankiv district. *Environment International*, 146, article number 106282. doi: 10.1016/j.envint.2020.106282.
[13] Law of Ukraine No. 791a-XII "On the Legal Regime of the Territory that has been Subjected to Radioactive Contamination as a Result of the Chernobyl Disaster". (1991, February). Retrieved from https://zakon.rada.gov.ua/laws/show/791%D0%B0-12.
[14] Lazarev, M., Klepko, A., & Kalachniuk, L. (2024). *Biochemical blood parameters of cattle during long-term detention in a radionuclide-contaminated territory*. Kyiv: NULES of Ukraine.
[15] Lazarev, M.M., Klepko, & A.V. (2023). Assessment of hematological and immunological blood parameters in cattle with "Iodine" pathology after the Chernobyl accident. *Biological Systems: Theory and Innovations*, 14(1-2), 5-12. doi: 10.31548/biologiya14(1-2).2023.008.
[16] Liu, T., *et al*. (2020). Ultrasmall copper-based nanoparticles for reactive oxygen species scavenging and alleviation of inflammation related diseases. *Nature Communications*, 11(1), article number 2788. doi: 10.1038/s41467-020-16544-7.
[17] Mushawwir, A., Arifin, J., Darwis, D., Puspitasari, T., Pengerteni, D.S., Nuryanthi, N., & Perman, R. (2020). Liver metabolic activities of Pasundan cattle induced by irradiated chitosan. *Biodiversitas Journal of Biological Diversity*, 21(12), 5571-5578. doi: 10.13057/biodiv/d211202.
[18] Ostapchenko, L.I., Kalachniuk, L.H., Garmanchuk, L.V., Kuchmerovska, T.M., Arnauta, O.V., Arnauta, N.V., & Smirnov, O.O. (2019). *Theoretical and methodical funda mentals of the study of metabolic processes in human and animals using blood indicators*. Kyiv: NPE Yamchynskyi O.V.
[19] Pareniuk, O., & Yasuda, N. (2021). Chornobyl exclusion zone: Current status and challenges. *Annals of the ICRP*, 50(1), 201-208. doi: 10.1177/01466453211028032.
[20] Pegolo, S., Giannuzzi, D., Piccioli-Cappelli, F., Cattaneo, L., Gianesella, M., Ruegg, P.L., Trevisi, E., & Cecchinato, A. (2023). Blood biochemical changes upon subclinical intramammary infection and inflammation in Holstein cattle. *Journal of Dairy Science*, 106(9), 6539-6550. doi: 10.3168/jds.2022-23155.
[21] Razavi, S.M., Yaghoobpour, T., & Nazifi S. (2023) A review on acute phase response in parasitic blood diseases of ruminants. *Research in Veterinary Science*, 165, article number 105055. doi: 10.1016/j.rvsc.2023.105055.
[22] Talerko, M.M., Lev, T.D., Drozdovitch, V.V., & Masiuk, S.V. (2020). Reconstruction of the radioactive contamination of the territory of Ukraine by Iodine-131 during initial period of the Chornobyl accident using the results from numerical model WRF. *Problems of Radiation Medicine and Radiobiology*, 25(8), 285-299. doi: 10.33145/2304-8336-2020-25-285-299.
[23] Vlizlo V.V., *et al*. (2012). *Laboratory research methods in biology, animal husbandry and veterinary medicine*. Lviv: SPOLOM.
[24] von Zallinger, C., & Tempel, K. (1998). The physiologic response of domestic animals to ionizing radiation: A review. *Veterinary Radiology & Ultrasound*, 39(6), 495-503. doi: 10.1111/j.1740-8261.1998.tb01639.x.
[25] Yang, H., Liu, L., Wang, M., Li, J., Wang, N.S., Du, G., & Chen, J. (2012). Structure-based engineering

of methionine residues in the catalytic cores of alkaline amylase from alkalimonas amylolytica for improved oxidative stability. *Applied and Environmental Microbiology*, 78(21), 7519-7526. doi: 10.1128/AEM.01307-12.

Біохімічні показники крові великої рогатої худоби за дії радіаційного опромінення

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Анотація. У сучасних умовах актуальним є вивчення адаптаційних процесів живих організмів, особливо дослідження біохімічних показників крові великої рогатої худоби (ВРХ) за її тривалого утримання на забрудненій радіонуклідами території. Метою роботи було визначити біохімічні показники крові, проаналізувати характерні зміни, їхній вплив на стан здоров'я тварин та оцінити ступень ураження організму радіоактивними ізотопами йоду. Визначено біохімічні показники (активність амілази, аспартат – і аланінамінотрансфераз (АСТ і АЛТ), глутатіонпероксидази (ГПО), концентрацію гідроперекисів ліпідів (ГПЛ), вмісту церулоплазміну, рівень загального білка у плазмі крові великої рогатої худоби за традиційними методами визначення біохімічних показників) і встановлено, що їхні значення коливаються в широких межах, але вони суттєво не відрізняються між групами тварин, котрі зазнали впливу різних доз іонізуючого опромінення (1 Гр на організм, 2 Гр на шлунково-кишковий тракт і до 40 Гр на щитоподібну залозу) за рахунок чорнобильських радіоактивних випадань, враховуючи радіоактивний йод на щитоподібну залозу, і тварин, що утримувалися на відносно чистій території, тобто без суттєвих доз опромінення (на рівні декількох мГр). Проаналізовано характерні зміни біохімічних показників та ймовірні зміни стану здоров’я і встановлено: за умов опромінення щитоподібної залози у великих дозах (40 Гр на ЩЗ) в організмі спрацьовують потужні механізми адаптації, які нівелюють на організменному рівні негативну дію іонізуючої радіації і зберігають такі важливі господарські ознаки як відтворювання і продуктивність. Звідси, дані дослідження можуть бути підґрунтям для формування системи заходів регуляції механізмів адаптації організмів за впливу екопатогенних факторів

Ключові слова: йод стабільний (^{127}I); йод радіоактивний (^{131}I); забруднена радіонуклідами територія; щитоподібна залоза; кров; ензимна активність; біохімічні показники