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Peculiarities Of Cattle Metabolism In Conditions Of Industrial Agroecosphere.

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ABSTRACT

In this manuscript we present results of studying the functional features of manifestations of technogenic effects on the metabolism of cattle that are housed in a polluted zone. The indicators of protein metabolism in cattle revealed a significant change in the serum proteinogram, which is expressed by a decrease in the concentration of albumin and protective proteins: β- and γ-globulins; and an increase of α-globulins, against the background of a slight decrease in the level of total protein. The delay in the biosynthesis of proteins leads to the involvement of amino acids in indirect deamination and transamination, which is confirmed by the changes in the activity of transaminases. It was determined that the total glucose content in the blood serum is lower than the reference values by 21.74 – 27.67%, which is typical when heavy metals are effecting the organism of animals. The anaerobic oxidation of glucose is intensified, which is confirmed by the excess of the standard values of the lactate/pyruvate coefficient by 26.90 – 40.70%. We have established disorders of the intermediate lipid metabolism, which are expressed by lipidemia and hyper-β-lipoproteinemia. When hypoglycemia is developing, there is an increase of cholesterol concentration (one of the main regulators of glyconeogenesis) by 1.35 times. Mobilization of lipids is accompanied by activation of the processes of their peroxidation. The concentration of the final product of lipid peroxidation – the malondialdehyde, increases by 1.26 times. The increase in peroxidation processes is confirmed by a decrease in alkaline phosphatase activity by 21.95 – 26.63%. An imbalance of minerals in the blood has been established, which is manifested in a reduced level of essential content and accumulation of toxic elements. The excess of physiological parameters for iron, nickel, plumbum and cadmium was found at 52.98 – 78.54; 13.92 – 18.56; 9.68 – 11.29 and 2.00 – 6.00%, respectively.

Keywords: polluted zone, heavy metals, metabolic processes, cattle, protein metabolism, carbohydrate metabolism, lipid metabolism, essential elements.

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INTRODUCTION

Currently, the resolution of issues of agroecology related to the sustainable functioning of the soil-plant-animal-human system under industrial conditions is of particular relevance, especially when the interaction of human with the surrounding environment has caused many negative consequences. Modern literature has accumulated a lot of data confirming the dependence of the elemental composition of living organisms, including humans, on the content of chemical elements in the environment; that is, the composition of the internal environment of the organism is influenced by the external environment outside the organism. Initially, the concentration of an element in a living organism increases with an increase in its concentration in the external environment. Upon reaching certain levels of accumulation of the element in the internal environment, the body reduces the proportion of the incoming element (reduced absorption and increased excretion of a certain element) as a result of the inclusion of protective mechanisms and natural barriers of the organism [1,2,3,5,6,7,8,9]. Subsequently, there is either a slight further increase in concentration, or its cessation and maintenance of constancy, or saturation above physical limit concentrations, which leads to disruption of regulatory processes and manifests itself in the form of metabolic disturbances, dysfunction and even death of the animal [4]. Consequently, the current environmental situation significantly affects the animals. At the same time, the level of environmental pollution has a regional zone nature. In this regard, it is necessary to study the characteristics of metabolic processes in animals at the regionally, taking into account the environmental characteristics of the particular area.

The purpose of these experiments was to study the functional characteristics of the manifestations of anthropogenic effects on the metabolism of cattle that are housed in the environmentally polluted zone.

A STUDY OF METABOLISM CONDITIONS OF CATTLE, HOUSED IN INDUSTRIAL POLLUTED TERRITORY

To study the peculiarities of metabolic processes of cattle, taking into account the ecological characteristics, uniformity of housing and feeding conditions, the cattle breed and their productivity in identical farms, two groups with 12 cows in each were formed. They all had similar parameters: 480 – 500 kg of live weight, age 4 – 5 years, pregnancy period 3.0 – 3.5 months.

The choice of territory was carried out taking into account the environmental characteristics. Agricultural areas belonging to the zone of special environmental risk were selected due to landscape-geographical and meteorological features. By preliminary studies, we found that the farms on the basis of which the research is carried out are located on the territory in the soil cover of which the concentration of copper, zinc, manganese is below the permissible level by 25.52 – 73.46%; iron, nickel, cadmium is higher than the TLV (threshold limit value) by 1.50 – 6.40 times; the vegetable feed contains phosphorus, calcium, sulfur, magnesium, copper, zinc below the optimal by 18.40 – 63.68%; the concentration of nickel, plumbum, cadmium exceeds the TLV by 1.29 – 4.26 times.

The material for the study was whole blood and blood serum. The next biochemical parameters in the serum were studied: total protein – by the method of refractometry; protein fractions – by nephelometry, aspartate and alanine aminotransferase – by the Reitman-Frankel colorimetry test using the standard BIO-LA-TEST kit; alkaline phosphatase activity – by photocolorimetry using the KliniTest-SchP AMP kit; the urea content – by the color reaction method with diacetylmonooximone; total lipids – by Ilku-Dadichu colorimetric method; beta-lipoproteins – by the Burstein colorimetric method; cholesterol – by the Lieberman-Burchard reaction in Ilk's modification using a standard on the BIO-LA-TEST kit; glucose – by the glucose-oxidant method using the standard Glucose-PKD kit; calcium and phosphorus – using the standard KliniTest-R kit. In the whole blood we studied: pyruvic acid (PVC) – by the method of colorimetry in the modification of Umbright; lactic acid – by the method of colorimetry according to Barker and Summerson. The concentration of magnesium, iron, copper, zinc, manganese, cobalt, nickel, plumbum, cadmium in the blood was determined by atomic absorption spectrophotometry on an AAS-30 spectrophotometer.

CONDITIONS OF THE PROTEIN METABOLISM OF CATTLE

To study the nature of metabolic processes in animals, a number of biochemical indicators of protein, carbohydrate, lipid and mineral metabolism were studied.

Blood proteins perform many functions, and a change of their consentration in the blood leads to disruption of homeostasis and specific resistance of the organism.

According to the obtained data, the concentration of total protein in the serum of cows of both the first and second groups is lower than the physiological norm by 5.47 – 7.83% and amounts to 70.52±1.27 – 68.75±1.07 g/L, respectively (Tab. 1).

Table 1. Indicators of protein metabolism in the blood of cattle

Indicator	1st group	2nd group	Reference value
Total protein, g/L	70.52±1.27	68.76±1.07	74.60-81.30
Albumins, %	34.92±0.43	33.54±0.24	42.00-48.00
Globulins: α-, % ß-, % γ-, %	 33.15±1.09 9.48±0.17 22.45±0.54	 35.67±0.98 9.32±0.26 21.47±0.76	 16.40-22.40 10.00-16.00 25.00-27.20
Ceruloplasmin, g/L	1.14±0.02	1.07±0.05	1.30-4.50
Urea, mmol/L	4.88±0.09	5.18±0.12	3.32-4.15
Creatinine, mmol/L	169.29±6.43	173.54±5.67	40.00-180.00

Analysis of the proteinograms shows that the decrease in the total protein content is mainly due to the low molecular weight fraction of albumin and protective proteins: β-globulins and γ-globulins, which leads to a redistribution of protein fractions in the serum. The content of serum albumin is reduced in comparison with the reference value in animals of the 1st group by 16.86 and 2nd group - by 20.14%. The concentration of β-globulins was reduced in animals of the 1st group to 9.48±0.17, and in animals of the 2nd group - to 9.32±0.26%. In our opinion, the main reason for the decrease in the albumin content in the blood serum of cows is a violation of the synthesis of albumin in the liver and an increase in decay under the influence of the resulting toxic products, which is consistent with the opinion of several authors. So, cadmium inhibits protein synthesis in the liver of rats at the stage of translation initiation. The damaging effect of nickel is realized at the cellular and subcellular level, while its hepatocytopathic effect is more characteristic.

Gamma globulins are the protective proteins (since the main part of them has the properties of antibodies) and with adverse effects on the body, due to "irritation" of the system of phagocytic mononuclear cells and increased production of JgG, JgA, JgM, the level of this fraction of proteins increases [6,10,11,12].

However, high concentrations of immunosuppressant drugs that cause a weakening of the immune function, as a rule, affect the processes associated with the division of immunocompetent cells, and in our studies this is confirmed by a decrease in the concentration of γ-globulins. The concentration of gamma globulins in both 1st and 2nd groups is 22.45±0.54% and 21.47±0.76%, respectively, which is lower than the norm by 10.20% and 14.12%, respectively. At the same time, the albumin-globulin proportion (A/G) decreased in animals of the 1st group to 0.54 and of the 2nd group — to 0.51 (the standard value is 0.8–1.4), which indicates chronically occurring pathological processes in the body of studied cows [6].

The level of urea in the serum is slightly higher than the physiological norm and is 4.88±0.08 mmol/L in the 1st group and 5.18±0.12 mmol/L in the 2nd group. Based on the fact that urea is one of the metabolites of protein metabolism (the intermediate end product), it can be assumed that its increased concentration in blood serum indicates an intoxication of the organism.

The amount of creatinine in the blood of animals of both groups is 169.29±6.43 mmol/L and 173.54±5.67 mmol/L, which is within the upper limits of the physiological norm. In cases of the impact of damaging factors on cells, enzymes are released from the damaged organs and tissues into the blood, where they are recorded in increased amounts.

The change in the activity of serum aminotransferases in cows of the 1st and 2nd groups is approximately the same and indicates an increase in the activity of aspartate aminotransferase (ASAT) and alanine aminotransferase (ALAT), with a more pronounced increase in the concentration of ALAT (Tab. 2). This proposes liver cell damage affecting the cytoplasm and mitochondria.

The activity index of aspartate aminotransferase is increased in comparison with the reference value in animals of the 1st group by 62.27%, and in the 2nd group by 43.92% and amounts up to 2002.41±54.13 and 1775.97±38.79 nkat/L, respectively. The activity of alanine aminotransferase in cows of both groups exceeded the standard level by 69.86% and 57.68%, respectively.

Increase of the De Ritis ratio up to 1.87 and 1.80 units, respectively (standard value of 1.29—1.31 units), indicates the pathological processes occurring in the liver that increase the permeability of cell membranes.

Table 2. The activity of enzymes in the blood serum of cattle

Indicator	1st group	2nd group	Reference value
ASAT, nkat/L	2002.41±54.13	1775.97±38.79	984.00-1234.00
ALAT, nkat/L	1075.21±31.69	998.11±29.05	500.00-633.00
Alkaline phosphatase, nkat/L	376.91±16.37	354.39±13.75	483.00-1534.00
De Ritis ratio in units	1.87±0.02	1.80±0.04	1.29-1.31

We found a decrease of alkaline phosphatase activity in serum down to 376.91±16.37 and 354.39±13.75 nkat/L, respectively. It is possible that the inhibition of enzyme activity is associated with impaired mineral metabolism, since an optimal activity requires an adequate ratio of magnesium and zinc ions [6]. The suppression of alkaline phosphatase activity apparently contributes to the accumulation of metabolites of abnormal metabolism.

CONDITIONS OF THE CARBOHYDRATE AND THE LIPID METABOLISM OF CATTLE

The vital activity of animals, their physiological functions and productivity are ensured by a clear and constant regulation of the two main sources of energy – carbohydrates and lipids.

To assess the state of carbohydrate metabolism in cattle, we observed the level of glucose in the blood and the concentration of the main metabolites of carbohydrate metabolism – pyruvic and lactic acids (Tab. 3).

The results of the studies showed that the total glucose level in the serum of the 1st and the 2nd group is lower than the reference values by 21.74% and 27.67%, respectively. That glucose level (1.98±0.08; 1.83±0.07 mmol/L) is typical when heavy metals affect the animal organism. The level changes of main metabolites of carbohydrate metabolism in the blood of cows are unidirectional and confirm impaired liver function. However, the intensity of level increase of pyruvic acid and lactate is not the same. So, if the concentration of pyruvic acid is 119.88±2.99 µmol/L in blood of animals of the 1st group and 124.21±3.20 µmol/L in animals of the 2nd group (which exceeds the reference values by an average of 22%), the concentration of lactate increases more significantly and exceeds the physiological norm by 51.72% and 74.26%, respectively.

The accumulation of lactic acid, in our opinion, primarily indicates a lack of oxygen in the cells, in which the carbohydrate metabolism changes from aerobic to anaerobic form. At the same time, an increase in the lactate/pyruvate ratio by 26.90% in animals of the 1st group and by 40.70% in the 2nd group allows to conclude that under the influence of adverse environmental factors the cattle organism experiences an energy deficit.

It should be noted that hypoglycemia and predominantly anaerobic oxidation of carbohydrates contributes to increased lipolysis. Analysis of data on the study of lipid metabolism of cattle indicates an increase in the concentration of total lipids in the blood serum, which is 6.17±0.24 g/L and 6.14±0.15 g/L, respectively.

The level of ß-lipoproteins increased in animals of the 1st group by 11.35% and in animals of the 2nd group – by 5.81%; and as we see, a more intensive synthesis of ß-lipoproteins is observed in cows of the 1st group (8,24±0,12 g/L at the upper limit of the physiological norm of 7.4 g/L). These changes indicate a disturbance in the intermediate lipid metabolism, expressed by lipidemia and hyper-β-lipoproteinemia.

Table 3. Indicators of carbohydrate and lipid metabolism in the blood of cattle

Indicator	1st group	2nd group	Reference value
Glucose, mmol/L	1.98±0.08	1.83±0.07	2.53-4.89
Pyruvic acid, µmol/L	119.88±2.99	124.21±3.20	91.20-100.30
Lactic acid, mmol/L	1.85±0.04	2.12±0.06	1.06-1.22
Malondialdehyde, µmol/L	3.09±0.64	3.18±0.25	1.50-2.50
Total lipids, g/L	6.17±0.24	6.14±0.15	2.80-6.00
ß-lipoprotein, g/L	8.24±0.12	7.83±0.18	3.50-7.40
Cholesterol, mmol/L	4.98±0.10	5.42±0.17	2.55-4.02

The content of cholesterol as well as β-lipoproteins is higher than the reference values. In cows of the 1st and 2nd groups, the level of cholesterol is 4.98±0.10 and 5.42±0.17 mmol/L, respectively.

As a result of a decrease in the level of glucose and an increase in lipolysis in the body of cows of both groups, an accumulation of lipid peroxidation products (LOPs) occurs.

This is confirmed by an increase of concentration of the final LOPs product - malondialdehyde (MDA) by 1.24 – 1.27 times in comparison with the reference values. A decrease in the activity of copper oxidase (ceruloplasmin) must be noted, which serves as the protection of cell membranes from the toxic effects of products of both protein metabolism and peroxidation. A decrease in ceruloplasmin concentration down to 1.14±0.02 – 1.07±0.05 g/L and an increase of MDA content up to 3.09±0.64 – 3.18±0.25 µmol/L indicates violations in the link of lipid peroxidation – the antioxidant defense system of the organism (LOPs-AOS).

CONDITIONS OF THE MINERAL METABOLISM OF CATTLE

When studying the metabolism of animals that are in an area with an abnormal content of chemical elements in environmental objects, it is impossible not to take into account the state of the mineral metabolism, since the imbalance of mineral elements leads to disruption of metabolic processes.

The level of calcium in the blood serum of cows is lower than the physiological norm in th 1st and 2nd groups by 2.80 – 4.80% and is 2.38±0.07 mmol/L, respectively (Tab. 4).

The phosphorus concentration, on the contrary, is within the upper limits of the reference values and in animals of the 1st group is at 2.29±0.11 mmol/L and the 2nd at 2.21±0.12 mmol/L (normal rate at 1.68 – 2, 10 mmol/L).

The decrease in the calcium level is probably due to an excess of nickel, plumbum, and a lack of cobalt, manganese, and copper, since the first mentioned minerals are the calcium antagonists and the second minerals are the synergistics.

The magnesium concentration is reduced by an average of 10.50% and is at 0.75±0.02 mmol/L and 0.71±0.01 mmol/L, respectively. The decrease in magnesium content, in our opinion, is associated with a deficiency of this element in the cattle diet, as well as with an excessive content of potassium – the magnesium antagonist.

The content of total sulfur is significantly reduced and amounts to 3.12±0.08 mmol/L in the 1st group, and 3.41±0.07 mmol/L in the 2nd group (normal rate at 5.30 – 15.00 mmol/L). It is likely that such a decrease in the concentration of sulfur is primarily due to the low content of this element in the environment and its change of passage in the soil → plants → animals system. Also, a decrease in sulfur content is probably associated with hypoproteinemia, since up to 80% of sulfur is part of protein molecules and enzymes. In addition, sulfur in the body is used as the neutralization of toxic products and the formation of sulfates, in the form of which is excreted from the body during endogenous and exogenous intoxication.

The microelements in the blood of cattle are exposed to more significant changes. The concentration of iron in the blood of the studied cattle exceeds the norm by 52.98 – 78.54%. It should be noted that the concentration of copper and manganese is significantly below the norm. The level of copper content is below the norm in the 1st and 2nd groups by 1.97 – 2.08, manganese by 1.68 – 1.94 times, respectively.

The reduced concentration of manganese in the blood of the studied animals (0.54±0.01 and 0.47±0.02 µmol/L, respectively) at its sufficiently high level in feed, apparently, is due to its antagonistic interactions with other elements: calcium and phosphorus reduce the absorption of manganese from the alimentary canal; iron – rivalry for communication with transferrin in the blood and with superoxide dismutase – in mitochondria.

The relatively low content of zinc in the feed influenced its level in the blood of cattle. The low level of zinc (30.85±0.72 and 34.27±0.95 µmol/L) may also be associated with an increased concentration in the blood of its functional antagonists – cadmium and plumbum.

Table 4. Indicators of the mineral metabolism in cattle

Indicator	Cattle group		Reference value
	1st group	2nd group	
Calcium, mmol/L	2.38±0.04	2.43±0.07	2.5-2.75
Phosphorus, mmol/L	2.29±0.11	2.21±0.12	1.68-2.10
Magnesium, mmol/L	0.75±0.02	0.71±0.01	0.82-1.23
Sulfur, mmol/L	3.12±0.08	3.41±0.07	5.30-15.60
Iron, mmol/L	14.39±0.31	12.33±0.29	4.48-8.06
Copper, µmol/L	6.77±0.14	7.16±0.11	14.13-17.21
Zinc, µmol/L	30.85±0.72	34.27±0.95	45.90-76.50
Cobalt, µmol/L	0.83±0.02	0.81±0.01	0.51-0.85
Nickel, µmol/L	10.22±0.23	9.82±0.19	1.72-8.62
Plumbum, µmol/L	1.38±0.01	1.36±0.02	0.24-1.24
Cadmium, µmol/L	0.53±0.00	0.51±0.00	0.44-0.50

The cobalt concentration in the blood of animals of both groups is within the upper limit of the physiological norms (0.83±0.02 and 0.81±0.01 µmol/L, respectively; normal rate at 0.51 – 0.85 µmol/L) with sufficient high level of content of this element in the feeds.

Apparently, one of the reasons for this was the high concentrations of iron in the feeds, which rivals copper for the substance that transports ions through the intestinal wall.

We have identified elements in the blood of cattle, whose biological role has not been studied enough; the plumbum and nickel content in the blood significantly exceeds the reference values. The plumbum concentration in the 1st and 2nd groups exceeds the norm by 11.29% and 9.68% and amounts up to

1.38±0.01 µmol/L and 1.36±0.02 µmol/L, respectively. The concentration of nickel is 10.22±0.23 µmol/L and 9.82±0.19 µmol/L (normal rate up to 8.62 µmol/L). The content of cadmium is higher than the permissible concentration by 6.00% and 2.00%, respectively.

INFERENCE

- The optimal content of chemical elements in the environment of the studied area is changed: concentration of phosphorus, sulfur, copper, zinc, manganese in soil is below the permissible level by 25.52 – 73.46%; concentration of iron, nickel, cadmium is higher than the threshold limit value by 1.50 – 6.40 times; the vegetable feed contains phosphorus, calcium, sulfur, magnesium, copper, zinc below the optimal rate by 18.40 – 63.68%; the concentration of nickel, plumbum, cadmium exceeds the permissible levels by 1.29 – 4.26 times.
- Adverse environmental conditions of animals cause changes in metabolic processes, which are catabolic in nature and are accompanied by a decrease in albumin content by 17.05%; β- and γ-globulins – by 7.10% and 12.23%; an increase in the activity of ASAT by 53.14%, ALAT – 58.35%; an increase in the content of β-lipoproteins by 8.52% and cholesterol – 30.41%.
- An increase in the concentration of lactic acid by 1.6 times, pyruvic acid – by 21.7%, and the lactate/pyruvate ratio – by 33.8% indicates a hypoxic profile of carbohydrate metabolism. The intensity of the functional state of the antioxidant defense system of the organism is confirmed by an increase of the malondialdehyde content by 1.5 times.
- The excess of physiological parameters of iron in the blood of cattle is 52.98 – 78.54%; nickel 13.92 – 18.56%; plumbum 9.68 – 11.29%; cadmium 2.00 – 6.00%.

CONSLUSION

The content of chemical elements in the organisms of animals depends on their content in the soil, water and feeds. An imbalance of minerals in the blood of cattle, which is manifested by a reduced level of essential elements and accumulation of toxic elements, leads to functional changes that are expressed by albumin, beta and gamma globulin level decrease in the blood. Delay in the biosynthesis of proteins leads to the involvement of amino acids in indirect deamination and transamination, which is confirmed by the nature of changes in the activity of transaminases and contributes to the inhibition of alkaline phosphatase activity. The result of all this is a restructuring of the mechanisms of the adaptation process, accompanied by high energy costs.

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