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Influence of toxic load on milk producing ability

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Influence of toxic load on milk producing ability

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Abstract. The purpose of this study was to assess the impact of the total toxic load on milk producing ability of Holstein cows in the Vologda region. Samples of animal hair were studied by atomic emission and mass spectral analysis with inductively coupled plasma to determine the concentrations of chemical elements. Depending on the toxic load factor, the animals were divided into two groups: with a lower and higher coefficient relative to the studied sample. Evaluation of productivity was carried out on the materials accumulated in breeding enterprises during the control milking operation. The analysis of the results of the content of chemical elements in the wool of dairy cows revealed that animals with a high toxicity coefficient had statistically significantly higher values of Cu, Fe, Mn, Pb, Al, Ni, and V. There was a tendency toward higher rates of elements such as As, Cd, Hg, Sr, Zn, B, Ca, Co, Cr, I, Li, Mg, Na, P, Se, Si and Sn. It was found that with an increase in the toxic load on the animal organism, milk productivity decreases.

1. Introduction

Various types of industrial activities lead to environmental pollution by heavy metals. Long-term exposure to heavy metals such as lead, mercury, cadmium and arsenic is detrimental to the health of live-stock animals. Heavy metals primarily affect the liver, kidneys, brain, and other body systems [15]. It should be noted that heavy metals, having high toxicity, are able to accumulate in soil, plants and in dangerous concentrations enter the human body through the food chain [16].

Thus, knowledge of the physiological mechanism of the influence of heavy metals on metabolic processes occurring in a living organism is necessary to solve the problems of reducing their negative impact.

In conditions of rapid industrialization and urbanization, environmental standards are becoming obsolete; they do not reflect the level of environmental pollution. In this regard, many countries are reviewing the impact standards of individual elements [17, 19, 20]. In 2019, the US Environmental Protection Agency announced new standards for lead content in soil, dust, and paint [18]. Due to such measures, the risk and consequences of exposure to Pb on public health are reduced, especially in the perinatal period and childhood.

It should be noted that the effects of individual metals and metalloids do not constitute such a danger as their combined effect on the environment and living organism. Many studies focus on the study of individual isolated elements [21, 22, 24]. However, under natural conditions, the effect of a mixture of various metals predominates and, for example, cadmium pollution is inevitably associated with lead and zinc [23]. Therefore, the aim of this study was to assess the effect of the total toxic load on the milk production of Holstein cows.

2. Materials and methods

Experimental studies were carried out on a model of Holstein cows (n = 80) in the Vologda region. The live weight of animals during the selection of biosubstrates was 610–640 kg, age – 4–6 years.

Service and experimental studies on animals were performed in accordance with the protocols of the Geneva Convention and the principles of good laboratory practice (National Standard of the Russian Federation 53434-2009), as well as according to the recommendations "The Guide for the Care and Use of Laboratory Animals " (National Academy Press Washington, D.C. 1996). In carrying out the research, efforts were made to minimize animal suffering and reduce the number of samples used.

The design of the experiments was approved by the local ethics committee of the Federal Research Centre of Biological Systems and Agrotechnologies of the Russian Academy of Sciences (No. 4 of 02/05/2019).

To study elemental status, animal hair samples were used as biosubstrates [5]. Wool was selected according to the previously proposed method – at least 0.4 g from the upper part of the withers [1]. Sample preparation was carried out by ashing biosubstrates using a microwave decomposition system MD-2000 (USA). Analytical studies were carried out in the laboratory of ANO "Center for Biotic Medicine" (Moscow), atomic emission devices (Optima 2000DV, PerkinElmer Corp., USA) and mass spectral (Elan 9000, PerkinElmer Corp., USA) inductively coupled plasma analysis.

In order to assess the toxic load on the body of cows, the coefficient of total toxic load was calculated – K_{tox}. The advantage of this indicator is its independence from the dimension of individual indicators and, as a result, the ability to calculate integral parameters [2, 3].

The sum of the coefficients of individual heavy elements was used to calculate the toxic load coefficient (Mn, Fe, Cu, Zn, As, Sr, Pb, Cd, Hg):

$$K_{tox} = K_{Mn} + K_{Fe} + K_{Cu} + K_{Zn} + K_{As} + K_{Sr} + K_{Pb} + K_{Cd} + K_{Hg},$$

K_{Mn} ... .K_{Hg} is the ratio of the content of the element in the wool of a particular cow to the content corresponding to the 50th centile

Heavy metals were selected relative to the atomic mass of the elements – over 50 atomic units [4].

Assessment of the productivity of animals was carried out according to the materials accumulated in breeding enterprises during the control milking and subsequent assessment of the quality of milk.

Processing of the obtained data was carried out using methods of variation statistics using the statistical package "StatSoft STATISTICA 10". Storage of research results and primary processing of the material was carried out in the original database "Microsoft Excel 2010". Verification of the compliance of the obtained data with the normal distribution law was carried out using the Kolmogorov consent criterion. The hypothesis that the data belong to the normal distribution was rejected in all cases with a probability of 95 %, which justified the use of nonparametric procedures for processing statistical aggregates (Mann-Whitney U-test). The data obtained are presented as the median (Me) and the 25^{th}–75th quartile (Q_{25}–Q_{75}).

3. Results

The study of the elemental composition of the wool of Holstein cows bred on the territory of the Vologda region showed that the data obtained for almost all elements were in the range of recommended values [25]. The exceptions were As, Hg, and Li, the levels of which in almost all of the examined animals were above normal.

In general, the results of the analysis of the wool of cows of the Vologda region were satisfactory, in connection with which it was proposed to use the toxic load coefficient for a more detailed study of the results. Calculation of K_{tox} was carried out regardless of the biological significance of the elements.

According to the K_{tox} calculation, two groups were formed: group I (n = 25) included Holstein cows with a lower toxic load coefficient (K_{tox} = 6.9 (6.5–7.2)) relative to the sample studied; group II (n = 25) included cows with a higher toxic load coefficient (Kt_{ox} = 15.8 (13.5-24.6)) relative to the studied sample.

Analysis of the results of the content of chemical elements in the wool of dairy cows revealed that animals of the second group had statistically significantly higher values of Cu, Fe, Mn, Pb, Al, Ni and V. Among the essential elements, it was noted that the level of iron was statistically significantly higher in the second group, where the Q_{25} value of this element was 78 % higher than Q_{75} ($p = 0.008$) relative to the first group. In the same group, a significantly higher copper content was observed – Q_{25} was higher than Q_{25} of the first group by 26 % ($p = 0.03$). Manganese was also higher – Q_{25} was higher than Q_{75} by 80 % ($p = 0.003$) (Figure 1).

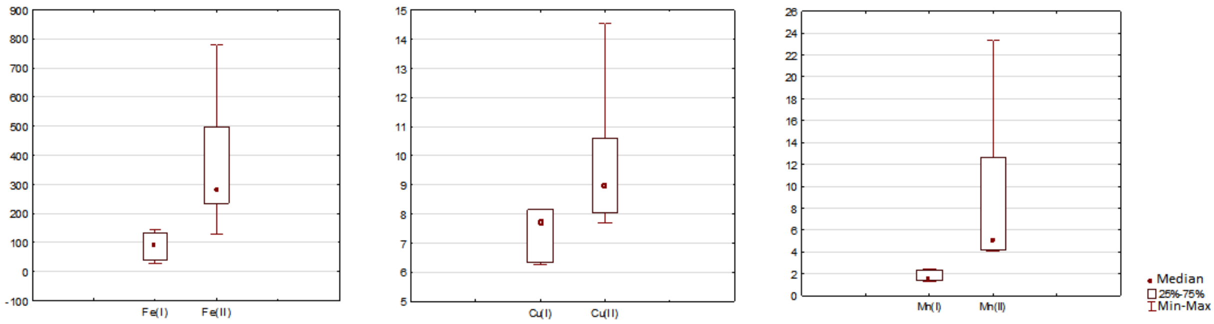

Figure 1. Concentration of Fe, Cu and Mn in wool in groups I and II, mg/kg

Among the potentially toxic and toxic microelements the following was observed: the level of lead in the second group was statistically significantly higher than that in the first – the Q_{25} value was 75 % higher than Q_{75} ($p = 0.005$); nickel – Q_{25} is more than Q_{75} by 93 % ($p = 0.03$). The level of aluminum was also significantly higher – the Q_{25} value was 50 % higher than Q_{75} ($p = 0.008$) relative to the compared group (Figure 2).

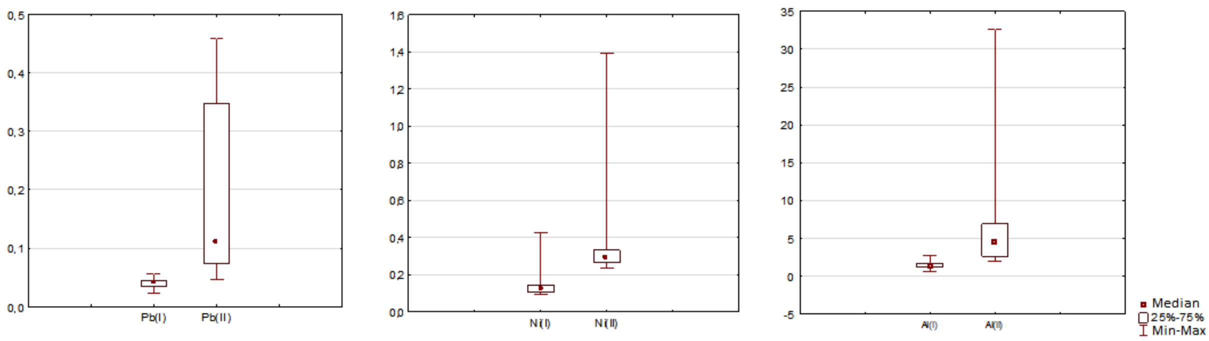

Figure 2. Concentration of Pb, Ni and Al in wool in groups I and II, mg/kg

It should be noted that for animals of the second group there was a tendency towards higher rates of such elements as As, Cd, Hg, Sr, Zn, B, Ca, Co, Cr, I, Li, Mg, Na, P, Se, Si and Sn. Against this background, the level of K was lower in the second group by 3 %.

With an increase in the toxic load on the animal organism, indicators of milk productivity decreased. In group II, there was a statistically significant decrease in average daily milk yield by 18 % ($p = 0.04$).

4. Discussion

Despite the fact that the level of almost all elements in the hair of the studied cows of the Holstein breed in the Vologda region was within the normal range, it was demonstrated that milk production decreases with an increase in the toxic load on the animal organism. In addition, studies of foreign and domestic scientists show that both acute and chronic effects of heavy metals on the body of farm animals lead to disruption of the functioning of many systems, including reproductive [13]. It is noted that in areas with high pollution, the costs of treating animals increase, and their mortality also increases [6–8]. Thus, the impact of heavy metals is the cause of economic losses in dairy farming.

In addition, the risk of the indirect influence of heavy metals on the health of the population, especially children, through food chains is increasing. Many authors point out that toxic metals are present in milk and other dairy products [10–12]. In one experiment, it was shown that oral feeding of lead acetate to cows leads to a significant increase in its excretion in milk [9]. Consequently, the consumption of such milk can have a negative impact on the health of the population, in particular, lead to impaired functioning of the cardiovascular and gastrointestinal systems, as well as become a cause of cognitive and intellectual disorders [11, 14]. In this regard, the next step in our work is to evaluate the composition of chemical elements in the milk of cows in the Vologda region.

In view of the growing environmental pollution, it is necessary to determine and control the levels of heavy metals in various biosubstars of dairy cows, since they can significantly affect the state of their morphophysiological systems, milk productivity, and mainly on human health.

5. Conclusion

Thus, in the course of the study, it was noted that with an increase in the toxic load on the animal organism, milk productivity decreases. The amount of product shortfall from dairy cows in the Vologda region may be associated with economic losses.

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