Elemental status of farm animals from different regions with different environmental loads

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Abstract. In this study, the elemental composition of the hair of Holstein cows (n=50) from two different regions of Russia (Vologda and Orenburg regions) was studied. The contents of chemical elements in wool of the animals was determined using ICP-AES and ICP-MS. According to the results obtained, there were significant differences in the content of practically all elements (with the exception of B and Cu) in the wool of cows when comparing animals from Vologda and Orenburg. The study of the mineral composition of cow hair has shown that territorial features are the determining factor of elemental homeostasis and clearly demonstrate the need to take into account regional features when developing recommendations for correcting the elemental status of animals.

1. Introduction

The problem of the content of chemical elements in the body of farm animals and livestock products is extremely relevant [1–4]. Microelements play a structural, physiological, catalytic and regulatory role in the animal body [5]. Thus, information about the content of trace elements is of great importance for the maintenance and growth of the body, as well as for achieving the maximum productive potential of cattle [6].

The food chain is an important source of chemical element accumulation. Significant amounts can be transferred from the soil to plants, causing the accumulation of various elements in grazing ruminants [7]. The accumulation of certain elements causes toxic effects both in animals themselves and in people who consume their meat and milk [8, 9].

Animal feed is traditionally supplemented with trace elements in concentrations that significantly exceed the physiological needs. However, environmental problems have led to the need for a more effective adaptation of the mineral supplement to the actual physiological needs and, in this context, not only the breed of the animal, but also its habitat is of great importance [10].

Taking into account the medical and social significance of microelements, knowledge of regional biogeochemistry is of fundamental importance, which is the basis for biogeochemical zoning and allocation of biogeochemical provinces. The body's reactions to the deficit or excess of chemical elements in the environment are caused by adaptive mechanisms developed in the course of evolution under conditions of variability of the biogeochemical environment [11]. It is known that the geochemical environment and living matter are interdependent components of the biosphere. In the biogeochemical cycle, complex cause-and-effect relationships are formed between the content of chemical elements in the external (geochemical) environment and the internal environment of living organisms. Farm animals are also one of the links in natural biogeochemical chains. The elemental composition of their body
depends on both the geochemical environment (a complex of natural factors) and socio-environmental factors, in particular, on the characteristics of water and food rations [11].

2. Purpose of research
Previous studies have shown the possibility of using indicators of the content of chemical elements in the wool of cattle as an indicator of monitoring their health [12]. In this regard, the purpose of this study was to study the elemental composition of the wool of Holstein cows from two different regions of Russia (Vologda and Orenburg regions).

3. Materials and methods
Experimental studies were conducted on Holstein cows (n=50). Depending on the territorial location of farms, 2 groups were formed: I group (Vologda region) – Agrofirma «Vologda» (n=25) and II group (Orenburg region) – Agrofirma «Promyshlennaya» (n=25). The live weight of animals during the selection of biosubstrates was 610-640 kg, age 4-6 years. Maintenance 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 GOST R 53434-2009), as well as in accordance with the recommendations of «The Guide for the Care and Use of Laboratory Animals (National Academy Press Washington, D.C. 1996)». When performing 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 Center of Biological Systems and Agrotechnologies RAS (№ 4, 05.02.2019).

Wool samples were used as biosubstrates to study the elemental status. Wool was selected according to the previously proposed method – at least 0.4 g from the upper part of the withers [13]. Analytical studies were conducted in the laboratory of the ANCO «Center for Biotic Medicine» (Moscow), at the ICP-AES and ICP-MS. The statistical processing of digital material was carried out using the application «Excel» and «Statistica 6.0». The statistical significance of differences between the groups was assessed using the Mann-Whitney U-test.

4. Results
Differences in the content of elements in cow wool when comparing groups I and II (Vologda and Orenburg regions) are shown in table 1.

| Element | Group I | Group II |
|---------|---------|----------|
| K       | 610-640 | 610-640  |
| Na      | 610-640 | 610-640  |
| Mg      | 610-640 | 610-640  |
| Ca      | 610-640 | 610-640  |
| Fe      | 610-640 | 610-640  |
| Zn      | 610-640 | 610-640  |
| Cu      | 610-640 | 610-640  |
| Mn      | 610-640 | 610-640  |
| B       | 610-640 | 610-640  |
| Si      | 610-640 | 610-640  |

The content of macronutrients such as K and Na was significantly higher in group I, while Q_{25} of this group was higher than Q_{25} of group III by 46 and 23 %, respectively. Among the essential elements of animal hair from the Vologda region, significantly lower values of Co, Cr, Fe and Mn were observed, while Q_{75} of group I was lower than Q_{25} of group III by 76, 81, 62 and 84 %, respectively. The exception was I, whose Q_{25} in group I was 68% higher than Q_{75} in group III; and Cu, whose content did not undergo statistically significant changes. The content of all conditional-essential elements was significantly lower in animals from the Vologda region, with the exception of B, the value of which did not undergo statistically significant changes. The values of Q_{75} Ni, Si and V of group I were lower than Q_{25} of group III by 78, 22 and 95 %, respectively. When analyzing toxic elements, significantly lower values of Cd, Sr and Pb were observed in the wool of group I animals, while Q_{25} of this group was lower than Q_{75} of group III by 27, 16 and 81 %, respectively.

Thus, we can note higher values of essential, conditional-essential and toxic elements in group II. It is particularly important to note the higher content of toxic elements (figure 1).

5. Discussion
The use of wool is very popular in Toxicological, Biogeochemical and Environmental studies, but exogenous contamination and unreliable reference values limit the usefulness of farm animal wool as a biomarker of exposure to chemical elements [14].

The revealed differences in the content of elements in wool when comparing animals of the Vologda and Orenburg regions are most likely due to the fact that the Vologda region is part of the
North-Western Federal district and is geographically remote from the Orenburg region, which is part of the Volga Federal district.

Table 1. The content of chemical elements in the wool of Holstein cows of the Agrofirma «Vologda» and Agrofirma «Promyshlennaya», mg/kg, Me (Q_{25}-Q_{75})

| Element Group depending on the geographical location of the farm | I group (Vologda region) | II group (Orenburg region) | p-level |
|---------------------------------------------------------------|--------------------------|---------------------------|---------|
| **Macroelements**                                             |                          |                           |         |
| Ca                                                            | 2468 (1301–2949)         | 3493 (1937–4247)          | 0.016   |
| K                                                             | 4271 (3630–5628)         | 2092 (1585–2485)          | 0.001   |
| Mg                                                            | 582 (281–760)            | 757 (617–953)             | 0.014   |
| Na                                                            | 1488 (1254–1641)         | 666 (518–1012)            | 0.001   |
| P                                                             | 255 (222–295)            | 214 (191–234)             | 0.023   |
| **Essential elements**                                        |                          |                           |         |
| Co                                                            | 0.036 (0.024–0.063)      | 0.312 (0.264–0.414)       | 0.001   |
| Cr                                                            | 0.168 (0.135–0.234)      | 1.750 (1.280–2210)        | 0.001   |
| Fe                                                            | 129 (52.2–203)           | 695 (535–1073)            | 0.001   |
| Cu                                                            | 8.15 (7.61–8.67)         | 8.35 (7.78–9.01)          | 0.366   |
| I                                                             | 2.05 (1.54–3.47)         | 0.65 (0.47–0.91)          | 0.001   |
| Mn                                                            | 3.13 (2.27–4.06)         | 29.6 (25.9–42.7)          | 0.001   |
| Se                                                            | 0.767 (0.537–0.861)      | 0.540 (0.424–0.667)       | 0.011   |
| Zn                                                            | 113 (103–141)            | 173 (137–213)             | 0.001   |
| **Conditional essential elements**                            |                          |                           |         |
| Li                                                            | 0.325 (0.297–0.413)      | 0.584 (0.418–0.766)       | 0.001   |
| B                                                             | 8.7 (2.6–10.4)           | 5.8 (3.3–7.16)            | 0.26    |
| Ni                                                            | 0.178 (0.126–0.265)      | 1.52 (1.21–1.94)          | 0.001   |
| Si                                                            | 2.3 (1.4–3.8)            | 7.8 (4.9–11.3)            | 0.001   |
| V                                                             | 0.034 (0.021–0.046)      | 1.33 (1.08–1.61)          | 0.001   |
| **Toxic element**                                             |                          |                           |         |
| As                                                            | 0.143 (0.112–0.185)      | 0.215 (0.176–0.279)       | 0.001   |
| Cd                                                            | 0.006 (0.002–0.013)      | 0.022 (0.018–0.036)       | 0.001   |
| Sn                                                            | 0.006 (0.003–0.004)      | 0.022 (0.015–0.033)       | 0.001   |
| Sr                                                            | 5.2 (2.8–7.4)            | 14.8 (8.9–20.9)           | 0.001   |
| Pb                                                            | 0.054 (0.042–0.090)      | 0.849 (0.486–1.73)        | 0.001   |

Figure 1. Concentration of Pb (a) and Cd (b) in wool in groups I and II, mg/kg
The Vologda region is generally considered a relatively favorable region compared to the Orenburg region [16], which is confirmed by our study. The hair of animals from the Orenburg region was characterized by higher values of essential, conditional-essential and toxic elements. An exceptionally important feature of the elemental status of animals in the Orenburg region, relative to Vologda, is the higher content of heavy metals in animal wool. Heavy metals are a general term applied to metals and metalloids that have a relatively high atomic density and are considered toxic to living organisms and the environment in certain concentrations [19, 20]. This term is widely recognized and is usually applied to elements such as cadmium, copper, iron, lead, zinc, etc., which are usually associated with issues of contamination and toxicity [21].

6. Conclusion
The study of the mineral composition of cow hair has shown that territorial features are the determining factor of elemental homeostasis and clearly demonstrate the need to take into account regional features when developing recommendations for correcting the elemental status of animals.

Thus, the geochemical features of the territory are a permanent environmental factor that affects the elemental status and mineral exchange of animals and can exert biological loads and determine the state of animal health.

Knowledge of the biogeochemical characteristics of the territory can help in the development of modern biogeochemical technologies in animal husbandry; this is primarily the fight against microelements in farm animals, the development of biogeochemical monitoring, obtaining balanced macro-and microelements of food and feed.

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