The effect of the state of "loaded metabolism" assesses the level of lead in the productivity of dairy cows

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Annotation. The study was performed on clinically healthy cows of Holstein breed during the period of milking in the CJSC "Gatchina" of the Leningrad region (Russia). Animals (n = 60) were divided into groups depending on the severity of "loaded metabolism" estimated by lead concentration in wool: up to the 25th centile, within the 25th to 75th centile, above the 75th centile. The concentration of lead in wool was determined by atomic emission and mass spectrometry (AES-ICP and MS-ICP). It was found that about the increase in lead content from the minimum to the maximum in centile intervals from 25-75 to > 75, the level of malondialdehyde (Total-MDA) in the blood increased, which was recorded against the background of a decrease in milk productivity. A significant negative correlation was observed between the concentration of lead in wool and the yield of milk fat, protein, dry matter, and corrected for 1% milk fat.

1. Introduction
Toxic chemical elements in metabolism alter the biochemical and physiological parameters of productive animals. This condition has received the definition of "loaded metabolism" [1] and is accompanied by stress detoxification systems and ultimately leads to a decrease in productivity [2]. One of the common toxic elements is lead [3].

Lead ingested with food, water and inhaled air, lead can adversely affect animal health [4,5] and, even at low concentrations, accumulates in bones, brain and other organs [6], causes oxidative stress [7].

To assess the level of lead in the body, elemental analysis of various biosubstrates, including wool, is used. Earlier studies have shown that the mineral composition of hair indicates the concentration and activity of chemical elements in other parts of the body and reflects the elemental status of dairy cows [8], while the concentration of chemical elements in the hair significantly correlates with the content of essential and toxic elements in the blood [9].

The importance of monitoring and correcting low concentrations of lead in the body is recognized in medicine [10], which undoubtedly requires decisions to reduce its content in animal products.

In this regard, the purpose of this experiment was to assess the effect of the exchange pool of lead, assessed by its concentration in wool from the withers, on the level of malondialdehyde in the blood and the milk productivity of Holstein cows.
2. Materials and methods
2.1 Object of study
The study was performed on clinically healthy cows (n = 60) of a Holstein breed with a live weight of 510–540 kg. Lactation stage - 25-55 days after calving.

Animal care and experimental studies were carried out in accordance with the instructions and recommendations of the Order of the Ministry of Health of the USSR of July 27, 1978 No. 701 “On Amendments to the Order of the Ministry of Health of the USSR of 12.08.77 No. 755” and “The Guide for Animals” (National Academy Press, Washington, DC 1996). In carrying out the work, efforts were made to minimize the suffering of animals and reduce the number of samples used.

2.2 The scheme of the experiment
The experimental part of the work was carried out at CJSC Gatchina in the Leningrad Region. Animals (n = 60) were divided into groups depending on the lead concentration in wool: group I - up to the 25th centile (n = 15; interval 0.026–0.046 μg / g), II - within the boundaries of the 25-75th centile (n = 30; interval 0.051–0.142 μg / g); Group III — above the 75th centile (n = 15; interval 0.146–0.248 μg / g).

When choosing centile intervals, we relied on the work previously performed on human biosubstrates [11].

2.3 Sampling and analysis of hair samples
Wool samples (weight 0.4 g) were taken from the top of the withers of cows [12] with stainless steel scissors. The lead concentration in the samples was determined by atomic emission and mass spectrometry (AES-ICP and MS-ICP).

2.4 Sampling medium milk samples
Milk samples were taken from each cow three times a day during each milking. The samples were determined by the concentration of fat, protein and dry matter.

2.5 MDA rating
Blood samples (9 ml) were taken from each cow from the tail vein into a vacuum tube. The degree of lipid peroxidation (LPO) was judged by the accumulation of the reaction product of malonic dialdehyde (Total-MDA) with thiobarbituric acid (TBA).

2.6 Statistical analysis
The significance of differences was checked using the Mann-Whitney U-test. The correlation coefficients were calculated by Spearman (Kc). The level of significance (P) was taken to be less than or equal to 0.05. For data processing, the software package Statistica 10.0 (StatSoft, Inc., USA) was used. The figures show the average values of indicators (M) and their standard deviations (± STD).

3. Results
Animals of group III were 5.3 (P≤0.001) and 2.4 times (P≤0.001) superior to analogues of groups I and II in lead concentration in wool (Fig. 1).
As the lead content increased from the minimum to the maximum in the centile intervals 25-75> 75, the level of malondialdehyde in the blood increased by 12.8 (P ≤0.05) and 20.7% (P 0.05), respectively (rice 2).

Indicators of milk production of cows, depending on the concentration of lead in wool from the withers are presented in Figure 3.
Figure 3. Milk productivity indicators of Holstein cows depending on the level of lead concentration in wool from the withers: (a) - milk fat yield, kg / day; (b) - yield of milk protein, kg / day; (c) - milk solids yield, kg / day; (d) - average daily yield adjusted for 1% fat, kg / day

As the results of the experiment showed, the yield of fat, protein, dry matter and the average daily milk yield of 1% for milk fat in cows with the maximum level of lead in wool (group III) were lower than in groups I and II by 20.2 (P ≤ 0.05) and 5.2% (P ≤ 0.05); 9.7 (P ≤ 0.05) and 0.9%; 11.5 (P ≤ 0.05) and 4.3%; 20.2 (P ≤ 0.05) and 4.9% (P ≤ 0.05), respectively.

The Spearman’s rank correlation coefficients calculated for the entire animal sample showed a significant relationship between the lead concentration in wool and the yield of milk fat (r = -0.51; P ≤ 0.05), protein (r = -0.38; P ≤ 0.05), dry matter (r = -0.49; P ≤ 0.05) and adjusted for 1% milk fat (r = -0.51; P ≤ 0.05) in the examined cows.

4. Discussion

Our findings are consistent with previous studies assessing the effects of toxic elements [13–15, 2], and lead on livestock productivity [16]. The obtained levels of lead concentrations in the hair of cows correspond to previously published studies [9, 17].

The explanation of the reasons for the relatively low productivity of cows with a high lead content in wool is possible considering information about the negative effect of this element on animal health [18], including through the development of oxidative stress [19,20]. At the same time, confirmation of the development of oxidative stress is an increase in the level of malondialdehyde (Fig. 2), as one of the reliable and frequently used markers of oxidative stress [21]. In our study, it was established that as the “exchange pool” of lead in the body of cows (Pb concentration in wool) increased from the lowest (1...
group) to medium (II group) and high (III group), the level of malondialdehyde in the blood serum increased by 12.8 (P≤0.05) and 20.7% (P≤0.05), respectively.

The development of oxidative stress, the accumulation of reactive oxygen species [22] lead to the depletion of antioxidant protection [23,24]. Antioxidant reactions of cows to oxidative stress require energy, which can be used to produce milk. As a result, increased oxidative stress may be accompanied by a decrease in milk yield indicators of cows. In addition, lipid peroxidation caused by oxidative stress leads to adverse changes in product characteristics and the nutritional value of milk. A significant effect of the concentration of malonic dialdehyde on the level of milk fat was established [25].

Thus, the lead exchange pool, assessed by the concentration in wool from the withers, is closely related to the intensity of lipid peroxidation and milk production. The data obtained in the experiment can be used to develop a technology for assessing the health status and functional status of highly productive dairy cows.

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**References**

[1] Miroshnikov S A, Notova S V, Zavyalov O A, Frolov A N and Egiazaryan A V 2018 *Animal elements of the animals: new technologies of diagnostics and correction* (Orenburg: Universit) 246 p

[2] Kalashnikov V, Zajcev A, Atroschenko M, Kalinkova L, Kalashnikova T, Miroshnikov S, Frolov A and Zavyalov O 2018 *The content of essential and toxic elements in the hair of the mane of the trotter horses depending on their speed* *Environmental Sci. and Pollution Res.* 25(22) 19961–7

[3] CDC (Centers for Disease Control and Prevention) 2012 *Sources of lead* Retrieved from: http://www.cdc.gov/nceh/lead/tips/sources.html (Access 26 March 2015)

[4] Sizova E, Miroshnikov S, Lebedev S, Kudasheva A and Ryabov N 2016 *To the development of innovative mineral additives based on alloy of Fe and Co antagonists as an example* *Agricultural Biology* 51(4) 553–62

[5] Sizova E, Miroshnikov S, Lebedev S, Levakhin Yu, Babicheva I and Kosilov V 2018 Comparative tests of various sources of microelements in feeding chicken-broilers V I View Correspondence *Agricultural Biology* 53(2) 393–403

[6] Tangpong J and Satarug S 2010 *Alleviation of lead poisoning in the brain with aqueous leaf extract of the Thunbergia laurifolia* (Linn.) *Toxicol. Lett* 198 83–8 doi: 10.1016/j.toxlet.2010.04.031

[7] Khordad E, Fazel A and Bideskan A E 2013 The effect of ascorbic acid and garlic administration on lead-induced apoptosis in rat offspring’s eye retina *Iran. Biomed. J.* 17 206

[8] Combs D K 1987 Hair analysis as an indicator of mineral status of livestock *J. Anim. Sci.* 65 1753–58 doi: 10.2527/jas1987.6561753x

[9] Patra R C, Swarup D, Sharma M C and Naresh R 2006 Trace mineral profile in blood and hair from cattle environmentally exposed to lead and cadmiumaround different industrial units *J. VetMedA.* 53 511–7

[10] Ordemann J M and Austin R N 2016 *Lead neurotoxicity: exploring the potential impact of lead substitution in zinc-finger proteins on mental health* *Metallomics.* Jun 8(6) 579–88 doi: 10.1039/c5mt00300h

[11] Skalnaya M G, Demidov V A and Skalny A V 2003 About the limits of physiological (normal) content of Ca, Mg, P, Fe, Zn and Cu in human hair *Trace Elements in Medicine* 4(2) 5–10

[12] Miroshnikov S, Kharlamov A, Zavyalov O, Frolov A, Duskaev G, Bolodurina I and Arapova O 2015 Method of sampling beef cattle hair for assessment of elemental profile *Pakistan J. of Nutrition* 14(9) 632–6
[13] Phillips C, Győri Z and Kovács B 2003 The effect of adding cadmium and lead alone or in combination to the diet of pigs on their growth, carcase composition and reproduction Retrieved from: https://doi.org/10.1002/jsfa.1548

[14] Raikwar M K, Kumar P, Singh M and Singh A 2008 Toxic effect of heavy metals in livestock health Vet World 1 28–30

[15] Schild C O, Giannitti F, Medeiros R M, da Silva Silveira C, Caffarena R D, Poppenga R H and Riet-Correa F 2019 Acute lead arsenate poisoning in beef cattle in Uruguay. J Vet Diagn Invest 31(2) 307–10 doi: 10.1177/1040638719831413

[16] Wang H, Jiang Y, Tian C, Pan R, Dang F, Feng J, Li M, Zhang Y, Li H and Man C 2018 Determination of the transfer of lead and chromium from feed to raw milk in Holstein cows Food Addit Contam Part A Chem Anal Control Expo Risk Assess 35(10) 1990–9 doi: 10.1080/19440049.2018.1496279

[17] Gabryszuk M, Sloniewski K, Metera E and Sakowski T. 2010 Content of mineral elements in milk and hair of cows from organic farms J. Elem. 15 259–67

[18] Struzyńska L, Dabrowska-Bouta B and Rafałowska U 1996 Acute lead toxicity and energy metabolism in rat brain synaptosomes Acta Neurobiol 57 275–81

[19] Sutton D, Tchounwou P B, Ninashvili N and Shen E 2002 Mercury induces cytotoxicity, and transcriptionally activates stress genes in human liver carcinoma cells. Intl. J. Mol. Sci. 3(9) 965–84

[20] Tangpong J, Satarug S 2010 Alleviation of lead poisoning in the brain with aqueous leaf extract of the Thunbergia laurifolia (Linn.) Toxicol. Lett. 198 83–8 doi: 10.1016/j.toxlet.2010.04.031

[21] Thompson G N, Robertson E F, and Fitzgerald S 1985 Lead mobilization during pregnancy Med. J. 143 131

[22] Tripathi R M, Raghunath R, Sastry V N and Krishnamoorthy T M 1999 Daily intake of heavy metals by infants through milk and milk products Sci. of the Total Environment 227 229–35 doi: 10.1016/S0048-9697(99)00018-2

[23] Valverde M, Fortoul T I, Diaz-Barriga F, Mejia J and del Castillo E R 2002 Genotoxicity induced in CD-1 mice by inhaled lead: Differential organ response Mutagenesis 17 55–61 doi: 10.1093/mutage/17.1.55

[24] Wong D L, Merrifield-MacRae M E, Stillman M J 2017 Lead (II) Binding in Metallothioneins Met. Ions Life Sci. 10 17 doi: 10.1515/9783110434330-009

[25] Zhao X J, Wang X Y, Wang J H, Wang Z Y, Wang L et al 2015 Oxidative stress and imbalance of mineral metabolism contribute to lameness in dairy cows Biolog. Trace Element Res. 164(1) 43–9 doi: 10.1007/s12011-014-0207-1