ACTA VET.BRNO,56,1987: 73-78

THE EFFECT OF MERCURY ON THE CATTLE ORGANISM

L. MALOTA

Department of Chemistry, Physics and Biochemistry, University of Veterinary Science, 612 42 Brno

Received September 18, 1985

Abstract

M a l o t a L.: *The Effect of Mercury on the Cattle Organism.* Acta vet. Brno,56,1987:73-78.

The effect of mercury on the catalytic activity of enzymes, the content of mercury in blood serum and in tissues as well as the time required for the separation of mercury from these tissues were investigated in fattened cattle. The inhibiting effect of mercury on the catalytic activity of AST, ALT and LDH was proved. An increase of the catalytic activity of enzymes under study was observed in the course of the third month of the experiment and a high concentration of mercury was also observed in the blood serum. A high concentration of mercury was found in the liver, kidneys and musculature. The time needed for the elimination of mercury from these tissues was about 5 months.

Mercury, residues, blood serum, liver, kidney, musculature, enzymes AST, ALT, LDH.

In agriculture, mercury compounds, especially the organic ones, are used as fungicides for seed dressing. Surplus seeds are sometimes an undesirable source of mercury contaminating the environment. Mercury occurs commonly also in foodstuffs and feeds in concentrations of 1 - 100 μg/kg. It is resorbed from the alimentary tract after binding to substance with a high degree of complex binding. Metallic mercury and water-insoluble mercury compounds must first be oxidized and converted to soluble compounds. In the organism the inorganic compounds are transported by the plasma, alkyl and aryl compounds are mostly bound to erythrocytes. The essence of the effect of mercury on the living organism can be explained by the denaturation of proteins and reaction with sulphydryl groups. In the organism mercury is retained mainly in the form of alkyl compounds - methylmercury and ethylmercury. The alkyl compounds are more toxic - LD_{50} p.o. 40 - 80 mg/kg of body mass (H a p k e 1975).

The aim of the present study was to find the ability of the cattle organism to absorb mercury from feed, to study its effect on the catalytic activity of some enzymes, to estimate the content of mercury in blood serum and tissues and to determine time need for the elimination of mercury from the organism.

Materials and Methods

A group of 10 fattening bullocks of a body mass less than 250 kg were used for studies of the content of mercury in blood serum and tissues, its effect on the catalytic activity of LDH (lactate dehydrogenase EC 1.1.1.27), AST (aspartate aminotranspherase. EC 2.6.1.1.) and ALT (alanine aminotranspherase EC 2.6.1.2). Blood was repeatedly collected from the v. jugularis externa in the course of 5 months. Ten bullocks of the same mass were taken as controls. The experimental group was fed wheat, dressed with Agronal which was used in a 12% proportion to the production of granulated feeds. One kg of granulated feed contained 3.723 mg of mercury and was fed for 18 days at a daily consumption of 2 kg per animal. After the coagulation of blood in test tubes under laboratory temperature the blood serum obtained was used for the individual analyses.

The catalytic activity of LDH was measured using the classical method (D z ú r i k 1967), the catalytic activity of AST and ALT using the Lachema Bio-La test. The Varian Techtron apparatus, model 634, was used for the measurements.

Mercury in the blood serum was measured using the AAS method after wet mineralization. Three ml of serum were put into a flask with a ground joint, and 2 ml of concentrated nitric acid and 5 ml of concentrated sulphuric acid were added. Mineralization was done under a reflux condenser with a fermentation cock and continued during the discharge of the brown vapours of nitrogen oxides till the content in the flask was completely clarified. After cooling down the content was put into a 50 ml flask and filled up with de-ionized water. Simultaneously, a blank sample was prepared in the same way. Mercury determination proper was done using the method of cold steam. Elementary mercury was obtained by a reaction with tin dichloride in a steam generator and after expulsion with inert gas into a quartz tube, the absorbance was measured. Setting of the Varian Techtron apparatus, model 1000: wave length 253.7 nm, slot 0.05 nm, hollow cathode current 3 mA, inert gas flow 140 kPa (4 l/min.). Tissue samples from both groups of animals killed during the experiment and taken at the end of the experiment were elaborated in the same way to find mercury residues.

Results

Figures 1 - 3 and Tabs. 1 and 2 give results obtained in investigations of the effect of mercury ions on cattle organism. The level of mercury ions in the blood serum is considerably fluctuating. A high level was observed in the 1st, 3rd and 4th month after feeding the contaminated feed. A very high level was found in the second half of the 3rd month when it was seven times higher than in the control group (Fig. 1).

The catalytic activity of AST decreased during the whole period under study, with the exception of the second half of the 3rd month when it rapidly increased (Fig. 2). The activity of ALT at first increased and then gradually decreased with a maximum in the second half of the 3rd month. After an initial increase the catalytic activity of LDH decreased, the maximum occurring in the first half of the 3rd month. In the second half of the 3rd month its activity rapidly increased and at the end of the period under study it decreased down to the values of the control group of animals (Fig. 3).

Tab. 1 gives the values of mercury in the tissues found one month after feeding the contaminated feed and Tab. 2 gives the values of mercury 5 months after feeding.

Tab. 1. Amount of Hg in tissues in $\mu g.kg^{-1}$ one month after feeding contaminated feed

animal No.	kidney	liver	musculature
115	16.930	905.7	69.5
116	1.343	1149.0	141.5
120	3.723	977.0	125.9
121	1.176	867.9	2.7
123	1.642	862.9	36.9

Tab. 2. Amount of Hg tissues in $\mu g.kg^{-1}$ 20 weeks after feeding contaminated feed

animal No.	kidney	liver	musculature
119	5.05	2.45	0.0
122	2.40	0.40	0.0
124	0.35	0.00	0.0

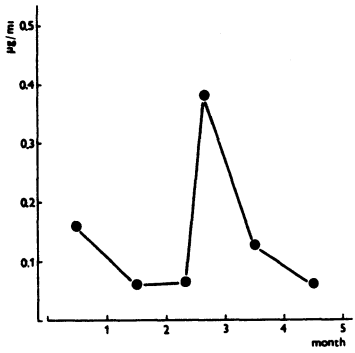

Fig. 1. Content of mercury ions in blood serum.

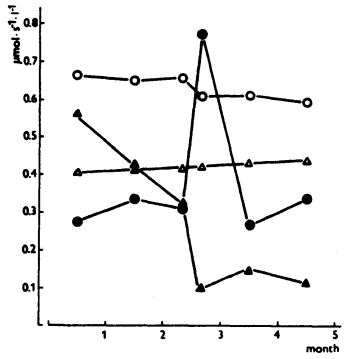

Fig. 2. Catalytic activity of AST and ALT in boold serum.
AST-(●) experimental group,
(○) control group,
ALT (▲) experimental group,
(△) control group

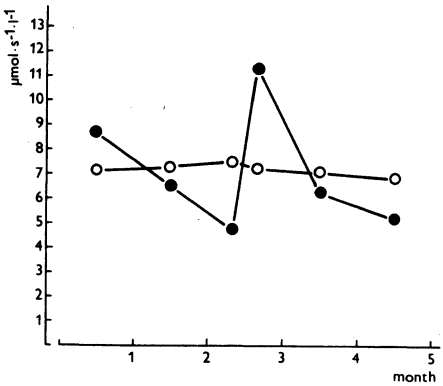

Fig. 3 Catalytic activity of LDH in blood serum. (●) experimental group, (○) control group

Discussion

The mechanism of the toxic effects of metallic ions on the living organism are based especially on the blocking of biologically functional groups, on the ability of substituting the biologically functional ions in the biomolecules and on the active change of the conformation of these moleculas as was given by N i e b o e r and R i c h a r d s o n (1980). Alkylated mercury compounds, especially methylmercury, have a firm bond between carbon and mercury in the molecule and they thus act toxically as a whole molecule. Agronal contains fenylmercurichloride (1.6% Hg) whose LD_{50} p.o. is about 100 mg/kg of live weight. K e l l n e r et al. (1975) described Agronal H intoxication of dairy cows. The results of the present study are different even though it is a similar case of mercury intoxication. In this case there was a decrease in the catalytic activity of the investigated enzymes AST, ALT and LDH. A temporary increase in the catalytic activity of LDH and ALT was recorded in the 1st and 2nd month after feeding the contamined feed and of AST and LDH in the 3rd month when a high level of mercury ions was found also in the blood serum.

In spite of the fact that 1 kg of granulated feed contained 3.723 mg of mercury, it did not appear in the clinical condition of the experimental animals giving evidence of mercury intoxication. Daily increments of the body mass ranged around 0.6 - 0.7 kg and were comparative with the control group of animals. Excessive amounts of uptaken mercury ions evidently did not damage the cellular structures, especially the tissues, in which mercury accumulated - kidneys, liver, musculature. With regard to the course of the curves of the catalytic activity of the enzymes investigated we can assume that it was namely this ability of mercury ions to block the functional groups of the enzymatic molecule, especially the -SH groups which decreased the catalytic activity. B a r t h o v á et al. (1977) proved the depressive effect of mercury on the -SH groups of LDH via noncompetitive inhibition. A temporary increase of the catalytic activity of LDH and AST during the 3rd month could have been due to the alternation of liver cells by a high level of mercury ions in the blood serum. The liver cells of mammals contain a greater amount of AST than ALT, and it is also its lower molecular weight that enables its easier passage through the membrane of the liver cell. A certain similarity appeared ion the period immediately after feeding the contaminated feed.

From the viewpoint of biochemistry, very important is the ability of these mercury ions to bind to red blood cells. N a g a n u m a et al. (1979), C h e n et al. (1974) drew attention to the fact that this binding and accumulation was promoted by selenium. If we follow the average length of the life of the erythrocytes, i.e. 110 - 120 days, then it is the very second half of the 3rd month that their disintegration takes place and at the same time the release of mercury ions bound to them. The high content of mercury ions in the blood serum in this period proves this situation. Their following passage into the liver and kidneys could cause a change in the permeability of cellular membranes and an increased level of enzymes in the blood.

C h e n et al. (1974) showed that mercury in the presence of selenium which decreases its toxicity is transformed from low-molecular proteins of the blood plasma to high-molecular proteins in the liver and kidneys. This form of binding, in the form of metalothioneine, is not toxic for the organism but is the cause of a long-term accumulation of mercury in these tissues. This has been proved also by the present results obtained when studying mercury residues in the tissues for 5 months after feeding contaminated feed. They confirm that mercury is cummulated especially in the kidney and liver for a long time and they prove that the process of eliminating mercury from the organism is considerably lengthy.

The present results prove that mercury impairs the stability of the internal environment of the organism through changes of the catalytic activity of the enzymes and that it endangers man as the consumer of animal products due to its capacity to cumulate in animal tissues and due to its very lengthy elimination from the animal organism.

The present results also stress the need for a consistent control of the use of chemical preparation in agriculture and in the case on intoxication with heavy metals to prevent the slaughtering of the animal until they are eliminated from the organism.

Vliv rtuti na organismus skotu

U skotu ve výkrmu byl sledován vliv rtuti na katalytickou aktivitu enzymů, obsah rtuti v krevním séru, obsah rtuti ve tkáních a čas potřebný pro vyloučení rtuti z těchto tkání. Byl prokázán inhibiční účinek rtuti na katalytickou aktivitu AST, ALT, LDH. Zvýšení katalytické aktivity sledovaných enzymů bylo pozorováno v průběhu 3. měsíce pokusu, kdy byla také v krevním séru zjištěna vysoká koncentrace rtuti. Vysoká koncentrace rtuti byla zjištěna v játrech, ledvinách a svalovině. Doba potřebná pro vyloučení rtuti z těchto tkání je asi 5 měsíců.

Влияние ртути на организм крупного рогатого скота

У откормочного скота проводили исследования блияния ртути на каталитическую активность энзимов, содержания ртути в кровянной сыворотке, содержания ртути в тканях и времени, необходимого для выделения ртути из упомянутых тканей. Было установлено ингибирующее действие на каталитическую активность AST, ALT, LDH. Повышение каталитической активности исследуемых энзимов наблюдалось в течение 3 месяца эксперимента, когда в кровяной сыворотке была также установлена высокая концентрация ртути. Высокая концентрация ртути была установлена в печени, почках и мышечной ткани. Необходимое время для выделения ртути из данных тканей - около 5 месяцев.

References

BARTHOVÁ, J. et al.: The function of sulfhydryl groups in lactate dehydrogenase isolated from soy-beam seedlings using blue dextran-sepharose. Collection Czechoslov. Chem. Commun., 42 , 1977. 3705-3711.

DZÚRIK, R.: Enzymológia. Bratislava, Obzor 1967, 199 p.

HAPKE, H.J.: Toxikologie für Veterinärmediziner. Stuthgart, F. Enge Verlag, 1975, 408 p.

CHEN, R.W. et al.: Diversion of mercury binding in rat tissues by selenium. A possible mechanism of protection. Pharm. Res. Commun., 6 , 1974: 571.

NAGANUMA, A. et al.: Effect of selenium on determination of mercury in animal tissues. Analyt. Biochem., 98 , 1979: 287-292.

NIEBOER, E. - RICHARDSON, D.H.S.: The replacement of the Nondescript term "Heavy metals". Environ. Pollut. B. Chem. Phys., 1 , 1980: 3-26.