Praca oryginalna *Original paper*

Transfer of selected toxic elements and bioelements from mother to offspring in the example of sheep*)

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Summary

The aim of the research was to investigate the transfer of heavy metals (lead (Pb) and cadmium (Cd)) and their antagonists in the group of essential micro-elements (magnesium (Mg), copper (Cu) and zinc (Zn)) from the organism of sheep to the organism of their offspring in milk. The research was carried out in two stages. The control group consisted of sheep with healthy milk glands, while the experimental group consisted of animals presenting subclinical mastitis. In the first stage of the research the distribution of toxic elements, Pb and Cd, administered per os to the mothers was studied by establishing their content in blood and milk. A measurable indicator for evaluating the transfer of toxic substances to milk, in both groups of animals was the content of the elements under investigation in the lambs' blood. The concentrations of Mg, Cu and Zn were also ascertained in the biological material collected. The aim of the second stage of the study was to evaluate the transfer of the heavy metals as well as the essential elements from the organism of the mother to the offspring through healthy and pathologically altered milk glands. The mothers were administered a mixture of salts of Cd, Pb, Mg, Zn and Cu, which activated mechanisms of antagonistic and synergetic interaction between the toxic metals and the essential elements, as illustrated by the content of these metals determined in the blood and milk of the mothers and in the blood of the lambs. A proof of a favorable influence of Mg, Cu and Zn on the content of Pb and Cd in the blood and milk of the mothers was a 4-5 times lower content of Pb in the milk of ewes, as compared with the first stage of the research. The per os administration of Mg, Cu and Zn to the ewes showed their statistically significant increase in blood as well as milk. The reduction in the levels of Pb and Cd in the ewes' milk, observed in the second stage of the research, was corroborated by their decreased content in the blood of the lambs in both groups of animals.

Keywords: lead (Pb), cadmium (Cd), zinc (Zn), copper (Cu), magnesium (Mg), milk, blood, mastitis, lambs

One of the first investigations into the transfer of toxic elements into milk was carried out in 1933 (9). The Pb content in women's milk was measured, and the concentration of Pb in the milk of women unexposed to that element was established as 56 μg/l. Similar values were obtained in later investigations, although a considerable differentiation in average Pb levels in milk were observed: from about 1 μg Pb/l (25) to 62 μg/l (22).

The content of toxic elements in woman's milk, by reason of their potential ecotoxicological consequences for humans, is a permanent subject of research (5). It is known that Pb can attain a high concentration in the milk of women exposed to intensive contact with this element. The milk of women living within a 200 m radius of a steelworks in Mexico showed high Pb concentrations of up to 350 μg/l (18). For 37% of these women the level of Pb in their milk exceeded 10 μg/l. It has been recognized that such a high concentration of Pb represents an important threat to the health of breast-fed newborn infants. Some research has shown that the Pb concentration in mother's milk is closely correlated with the level of Pb in the blood of the offspring. Moore et al. (19) carried out research on 17 mothers and their offspring. They demonstrated that the concentration of Pb in women's milk was on average 1/10 of the concentration in their blood. The same researchers showed that there was a high linear correlation between the levels of Pb in the blood of mothers and their offspring ($p < 0.001$). They also

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concluded that Pb levels in the blood of mothers and their offspring are influenced by the level of Pb in water. Breast-fed children absorbed less Pb than those fed artificially, in cases when the concentration of this element in water was high. In a research by Lacey et al. (13), the concentration of Pb in milk was 6% of its concentration in the blood of mothers; likewise, Ong et al. (22) showed that only 2% of the Pb concentration in the blood of mothers was detected in their milk. In the research carried out in Mexico, the levels of Pb in mothers' milk attained values of over 20% of the Pb levels established in their blood (18).

Research carried out on animals showed a considerable transfer of Pb to offspring through milk (4, 6, 8, 10-12, 14) as well as a considerably higher penetration of Pb into milk than has been noted in humans. In her research on rodents, Palminger-Hallén (23) showed the level of Pb in the milk and blood of adult females to be similar or in excess of the levels observed in the milk and blood of rabbits (14) and monkeys (25).

Newborns of mammals are characterized by quick changes occurring in the developing organs and in their functioning. Also the central nervous system develops rapidly during that period. Neurotoxic elements, such as Pb and Cd (3), pose a particular threat to the development of the brain. In the postnatal period, also metabolic functions differ from those of adults. In human newborns, the liver is characterized by low gluconeogenesis and a low production of plasma albumin. The functional development of the kidneys continues until the end of the first month of human life, and in rodents until the weaning period (25, 27). During this period, the presence of toxic metals in the organism is the most harmful, and even if there are no acute symptoms of poisoning, morphological and biochemical changes may pose a threat to health in later life.

In healthy mammary gland tissue, the basement membrane uniting glandular cells is impenetrable. In inflamed tissues, the cells move further apart from one another, which leads to the infiltration of blood plasma and tissue fluids. There occur significant changes in milk, which do not originate directly from milk-producing cells. As in all other inflammatory conditions, cells are more loosely connected to one another, and the intercellular spaces are filled with blood plasma. In such cases, the constituents of blood plasma (water, salts, blood albumin) can filter through the layer of loosely connected glandular cells to milk vesicles. The degradation of secretory vesicles in the mammary gland, resulting from the inflammatory condition, additionally increases its permeability. This fact is corroborated by changes in the composition of milk, which have been noted by several authors (16, 17).

Degradation changes which occur in glandular tissues in the course of an inflammation give rise to the hypothesis that there is a significant relationship between the health status of milk glands and the transfer of foreign substances into milk, including the toxic ions of heavy metals.

Based on these premises, an attempt was made to determine the impact of subclinical mastitis on the transfer of toxic elements (Pb, Cd) and their antagonists from the group of essential micro-elements (Cu, Mg, Zn) into the milk of sheep and into the blood of their offspring.

Material and methods

Procedures for forming experimental and control groups of animals. The research was conducted on Polish Mountain sheep. The animals qualified for the research were uniform in terms of their pedigree, age, lactation sequence, conditions of maintenance, nourishment and physiological state.

The health status of the animals was evaluated on the basis of clinical examinations: a general examination and a specific examination involving a clinical examination of mammary glands.

The evaluation of the health status of mammary glands was also based on the California test performed using the Mastitrapid preparation. Lobar secretion from the udders that showed doubtful and positive results in the test was collected for further laboratory tests to determine the etiological factor behind secretion disorders. Cytological examination of milk was also carried out, using the Fossomatic apparatus.

The main factor differentiating the control and experimental animals was the health status of their mammary glands: a subclinical inflammation of the udder. In stage I of the research, from the group of 123 mothers, 18 healthy animals were selected to the control group, and 18 ewes with subclinical mastitis were included to the experimental group. The lambs were qualified analogically: those from the control group mothers were put in the group of control lambs, and those from the experimental animals comprised the group of experimental lambs. In stage II of the research, 18 experimental animals and 18 controls were analogically selected, along with their lambs.

Stage I of research. The sheep were administered *per os* salts of Cd ($CdCl_2$ (POCH, Gliwice)) and Pb ($Pb(CH_3COO)_2 \times 3 H_2O$ (Merck)) in aqueous solutions at minimum effective doses (*dosis minima*) of 0.25 mg Cd/kg m.c. and 5 mg Pb/kg m.c. Such minimum effective doses were not dangerous to the health of the animals and were chosen upon consultations with specialists at the Department of Biochemistry and Toxicology and veterinary pharmacologists, as well as on the basis of data from literature (3, 24). They were also accepted by the local ethics committee, which concluded that the proposed procedure did not exceed the 2nd degree of invasiveness.

Aqueous solutions of the salts in 200 ml of distilled water were introduced into the rumen by means of a soft tube.

Blood and milk samples from the mothers were collected according to the following scheme:

– sample '0' – before the administration of Pb- and Cd-salt solution;

– sample '1' – 24 hours after the administration of Pb- and Cd-salt solution;

– sample ‘2’ – 72 hours after the administration of Pb- and Cd-salt solution;

– sample ‘3’ – 96 hours after the administration of Pb- and Cd-salt solution.

Stage II of research. Procedures for selecting sheep to the control and experimental groups were analogical to those in stage I. An innovation in stage II consisted in the single administration of a mixture of salts diluted in water, which included not only salts of Pb (5 mg Pb/kg m.c.) and salts of Cd (0.25 Cd/kg m.c.), but also salts of Mg, Cu and Zn in the form of sulphates, administered at 5 mg/kg m.c. each.

Blood and milk samples from the mothers were collected according to the following scheme:

– sample ‘0’ – before the administration of the Pb-, Cd-, Mg-, Cu-, and Zn-salt solution;

– sample ‘1’ – 24 hours after the administration of the Pb-, Cd-, Mg-, Cu-, and Zn-salt solution;

– sample ‘2’ – 72 hours after the administration of the Pb-, Cd-, Mg-, Cu-, and Zn-salt solution;

– sample ‘3’ – 96 hours after the administration of the Pb-, Cd-, Mg-, Cu-, and Zn-salt solution.

The test material in stages I and II of the research consisted of whole blood and milk from fully lactating mothers and blood from their offspring. Altogether, blood and milk were collected 8 times both from the ewes of the experimental group and from those in the control group; likewise, blood was collected 8-times from the lambs of both groups.

Specific volumes of the biological material (the blood and milk) were dried in a drier at a temperature of 105°C. The mineralization of the milk and blood samples was carried out at a temperature of 450°C in an electric oven, after which the ash was dissolved in nitric acid at a concentration of 1 mol/l. Quantity analysis for Cd, Pb and Cu content was carried out with a 220Z electrothermal atomic absorption spectrophotometer (with Zeeman-effect background correction); for Zn and Mg, however, an AAS-3 spectrophotometer was used (equipped with an EA-3 electrothermal atomizer and an MPS autosampler). All apparatus were produced by the Varian company.

Results and discussion

The analysis of interdependence between the investigated elements in stages I and II of the research. The statistical analysis of the content of the elements in the blood and milk of ewes, as well as in the blood of lambs in stages I and II of the research was carried out by Tukey’s Honestly Significant Difference test with a separate analysis of variance.

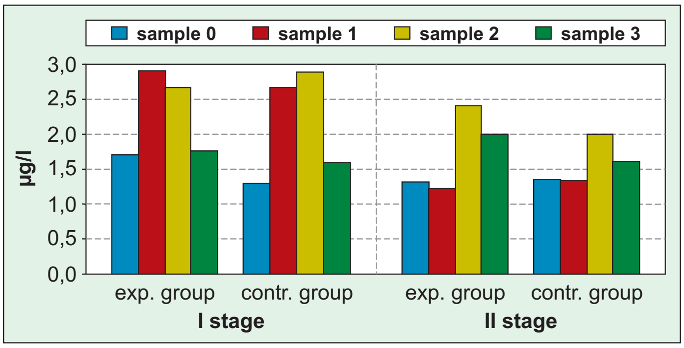

Fig. 1. Content of Cd in ewes’ blood in stages I and II of the study

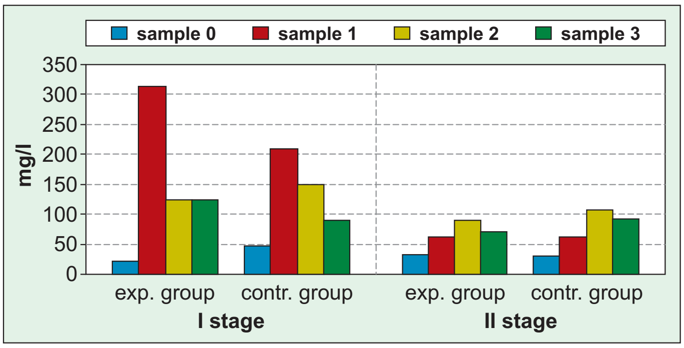

Fig. 2. Content of Pb in ewes’ blood in stages I and II of the study

The significance of differences between stages I and II in the mean content of the examined elements in the blood of ewes of the experimental and control groups is presented in table 1. The levels of the examined elements in the blood of the ewes in the course of the entire research is shown in fig. 1-5.

In the blood of ewes belonging to the experimental group (tab. 1), a significant difference was ascertained between the two stages of research concerning the mean value of Cd in sample ‘1’ and the mean value for all samples (fig. 1). In the case of Pb, there was also a highly significant difference regarding sample ‘1’ – in which the mean value of Pb in stage II was 5-times lower than in stage I – and the mean value for

Tab. 1. Significance of differences between stages I and II of the study in the content of elements in the ewes’ blood for experimental and control groups

Element	Experimental Group					Control Group				
	Sample				Mean	Sample				Mean
	0	1	2	3		0	1	2	3	
Cd	ns	0.000175	ns	ns	0.021862	ns	0.017536	0.037412	ns	0.033244
Pb	ns	0.002481	ns	ns	0.010292	ns	0.000371	ns	ns	ns
Zu	0.022874	0.001413	ns	ns	0.004275	0.012086	0.000099	ns	0.001200	ns
Cu	0.000003	ns	ns	0.000013	0.000266	0.007138	0.013331	ns	0.000008	0.006561
Mg	0.000006	0.000000	0.042464	ns	0.000001	0.000053	0.000000	0.015185	0.002496	0.000000

Explanation: ns – statistically not significant at the level p ≤ 0.05.

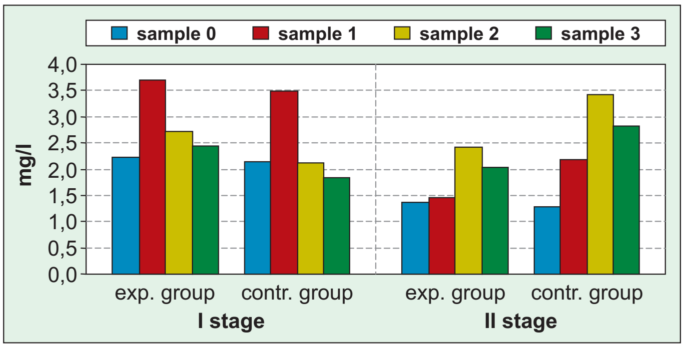

Fig. 3. Content of Zn in ewes' blood in stages I and II of the study

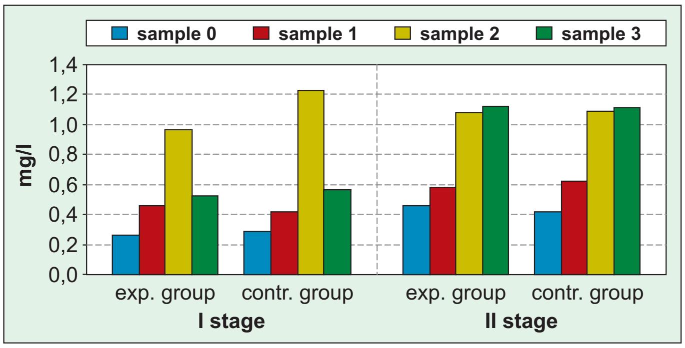

Fig. 4. Content of Cu in ewes' blood in stages I and II of the study

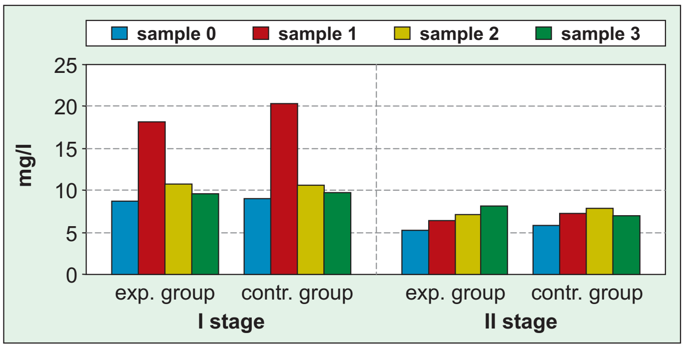

Fig. 5. Content of Mg in ewes' blood in stages I and II of the study

all samples (fig. 2). In stage II of the research, the content of Zn in the blood of ewes from the experimental group was significantly lower in samples '0' and '1' and as a mean value of all samples (fig. 3). Significant differences between the two stages in the values of Cu in the blood of the experimental animals were revealed in samples '0' and '3'. More than twice as much Cu was ascertained in the blood of animals in sample '3' in stage II. A significant difference was also shown in the mean value of all samples (fig. 4). A significant difference between stages I and II in the value of Mg was revealed in samples '0', '1' and '2', and in the mean value for all samples (fig. 5).

In the blood of ewes belonging to the control group (tab. 1), there was a significant difference between the two stages of the research regarding the mean content of Cd in samples '1' and '2'. In stage II of the research a significant drop in the content of this element was ascertained. Also the mean content of this element for all samples in stage II was significantly lower (fig. 1). In the case of Pb, a highly significant difference was noted between the stages in sample '1', in which the mean content of Pb dropped from 209.92 µg/l in stage I to 62.68 µg/l in stage II (fig. 2). Significantly less Zn was noted in samples '0' and '1' in stage II. In sample '3', however, the mean level of Zn was shown to be significantly higher in stage II (fig. 3). As to Cu, in stage II its content was significantly higher as a mean value for all samples and in samples '0', '1' and '3' (fig. 4). A significant difference between stages I and II in the content of Mg was observed in all samples, as well as in the mean value for all samples. The highest, a nearly 5-fold drop, was noted in sample '1'.

There were significant differences between stages I and II in the mean content of the examined elements in the milk of sheep belonging to both groups, as shown in tab. 2. The mean content of the elements in the milk of sheep in both stages of the research is depicted in fig. 6-10.

In the milk of the experimental ewes (tab. 2), no significant differences between the two stages of the research were observed in the mean content of Cd in any of the samples (fig. 6). However, a significantly high difference was observed between the two stages of the research in the mean content of Pb in milk. In stage I the levels of Pb in samples '1', '2' and '3' were several times higher than its levels in stage II. A significantly high difference was also observed in the mean value for all samples (fig. 7). The mean value of Zn in

Tab. 2. Significance of differences between stages I and II of the study in the content of elements in the ewes' milk for experimental and control groups

Element	Experimental group					Control group				
	Sample				Mean	Sample				Mean
	0	1	2	3		0	1	2	3	
Cd	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Pb	0.000551	0.002199	0.001387	0.000540	0.000865	ns	0.049211	0.014629	0.001411	0.004422
Zu	0.000009	0.006645	0.018429	0.000000	0.000000	0.000000	0.000001	0.002379	0.000000	0.000000
Cu	0.021004	0.021401	0.006110	0.001569	0.000063	ns	0.001841	0.000038	0.000003	0.000002
Mg	ns	0.000970	ns	0.000314	0.001270	0.020531	0.031305	ns	0.000328	0.000464

Explanation: as in tab. 1.

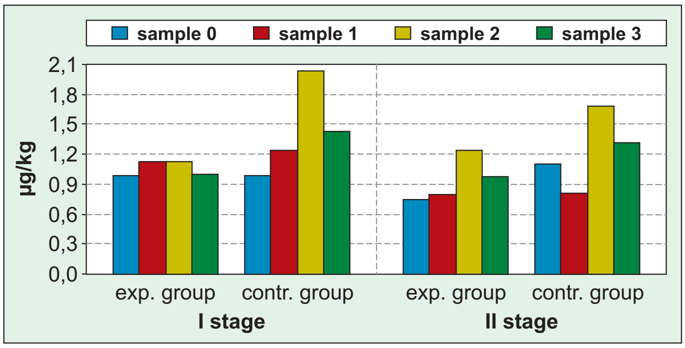

Fig. 6. Content of Cd in ewes' milk in stages I and II of the study

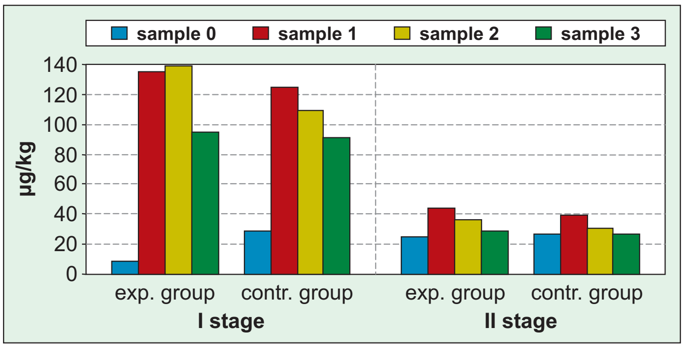

Fig. 7. Content of Pb in ewes' milk in stages I and II of the study

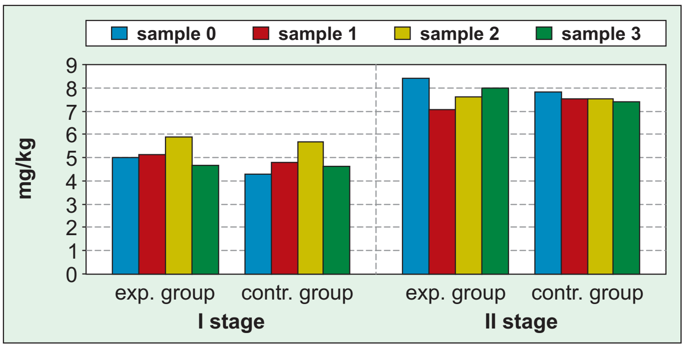

Fig. 8. Content of Zn in ewes' milk in stages I and II of the study

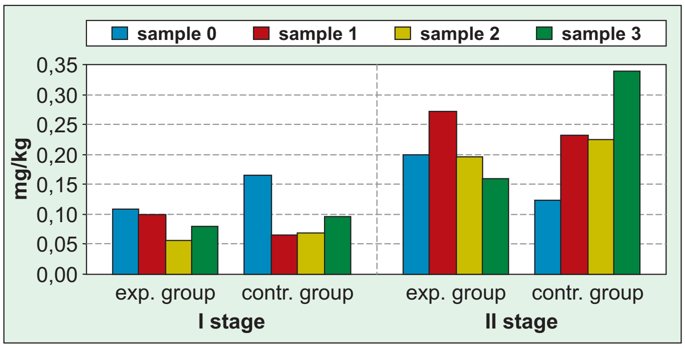

Fig. 9. Content of Cu in ewes' milk in stages I and II of the study

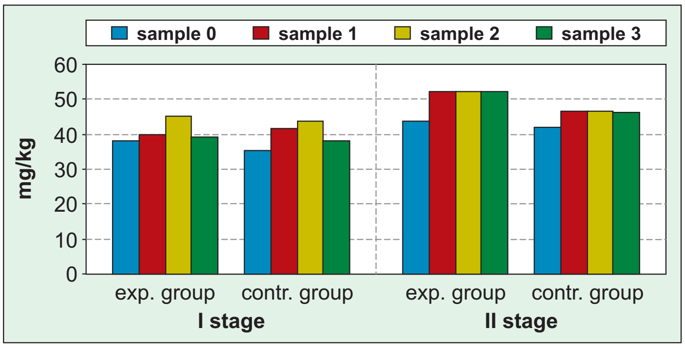

Fig. 10. Content of Mg in ewes' milk in stages I and II of the study

the milk of the experimental sheep was found to be significantly higher in stage II of the research in all four samples (fig. 8). In the case of Cu, a significantly high increase in its mean content was noted in stage II of the research. In the milk of the experimental animals, in all samples collected in stage II, the Cu content was 2-3 times higher than in stage I (fig. 9). In the case of Mg, significant differences between the stages were observed in milk samples '1' and '3' and in the mean value for all samples. Milk collected in stage II of the research had a significantly higher content of this element (fig. 10).

In the milk of ewes belonging to the control group (tab. 2) and the experimental group no statistically significant differences between the stages of the research were noted in the content of Cd (fig. 6). However, a highly significant differences were observed in the case of Pb in samples '1', '2' and '3'. The levels of this element in stage II were appreciably lower in comparison with stage I. A highly significant difference was also revealed in the mean value for all samples (fig. 7). The mean level of Zn in the milk of the control animals was shown to be significantly higher in stage II in all four samples (fig. 8). A statistically significant difference between the two stages of the research was also observed in the content of Cu. The Cu content in samples '1', '2' and '3', and its mean value for all samples were significantly higher in stage II (fig. 9). A significant difference between the stages in the case of Mg was noted in samples '0', '1' and '3', as well as in the mean value for all samples. The content of this element was higher in milk collected for tests in stage II (fig. 10).

Significant differences between stages I and II of the research in the mean content of the examined elements in the blood of lambs of both groups are presented in table 3. The mean content of the examined elements in the blood of the lambs is illustrated in fig. 11-15.

In the blood of the lambs from the experimental group (tab. 3) there was a significant difference between the stages of the research regarding the mean content of Cd in samples '1' and '2', and in its mean value for all samples. A highly significant decrease in the level of Cd in the blood of the lambs was noted in stage II of the research (fig. 11). The mean content of Pb in the blood of the experimental lambs was significantly lower in all samples collected in stage II of the research (fig. 12). In the case of Zn, however, a highly significant difference between the stages was only observed in sample '0'. The level of this element was

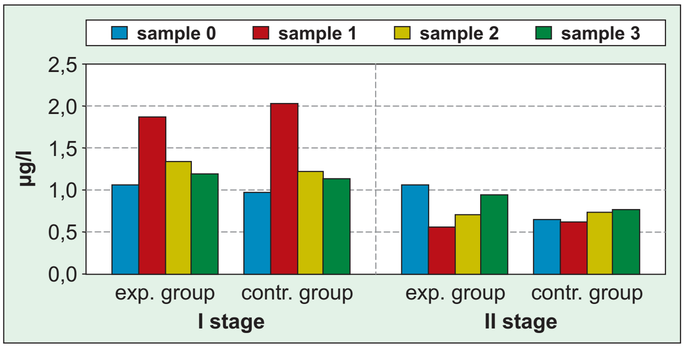

Fig. 11. Content of Cd in lambs' blood in stages I and II of the study

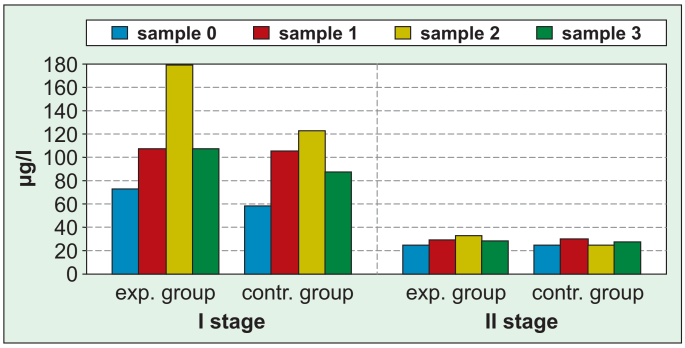

Fig. 12. Content of Pb in lambs' blood in stages I and II of the study

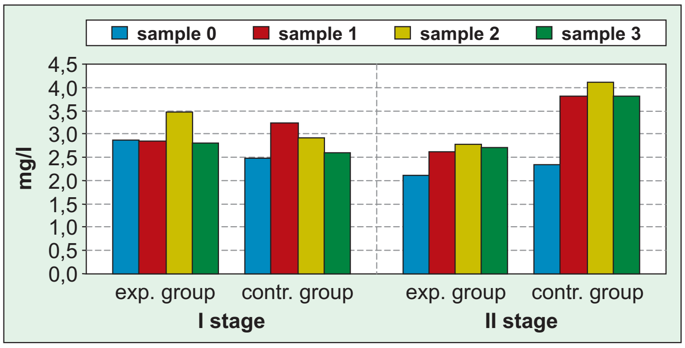

Fig. 13. Content of Zn in lambs' blood in stages I and II of the study

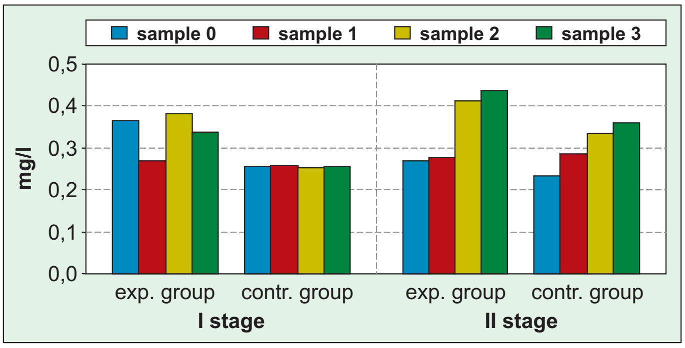

Fig. 14. Content of Cu in lambs' blood in stages I and II of the study

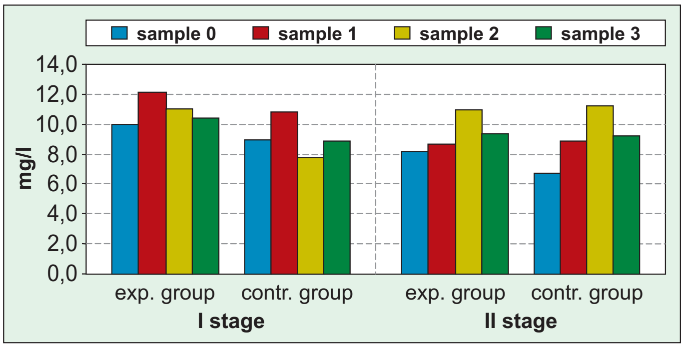

Fig. 15. Content of Mg in lambs' blood in stages I and II of the study

significantly higher in stage I (fig. 13). A significant difference between the stages in the mean content of Cu was noted in samples '0' and '3'. The mean level of Pb was shown to be significantly higher in sample '0' in stage II (fig. 14). In the case of Mg, a significant difference between the two stages of the research in the mean level of this element was only observed in sample '1' (fig. 15).

In the blood of lambs belonging to the control group (tab. 3) there was a significant difference between the two stages in the mean content of Cd in all samples. In stage II, the mean content of Cd in all samples was lower than in stage I: in sample '1' by as much as 75% (fig. 11). The Pb content was significantly lower in stage II in all samples collected and as a mean value of all samples (fig. 12). However, there was no significant difference between stages I and II in the content of Zn in the blood of the control lambs (fig. 13). A significantly higher level of Cu was noted only in sample '3' of stage II (fig. 14). In the case of Mg, a significant difference between the stages was observed in samples '0' and '2' (fig. 15).

Tab. 3. Significance of differences between stages I and II of the study in the content of elements in the lambs' blood for experimental and control groups

Element	Experimental group					Control group				
	Sample				Mean	Sample				Mean
	0	1	2	3		0	1	2	3	
Cd	ns	0.000663	0.000328	ns	0.000529	0.035501	0.005832	0.027908	0.001794	0.000547
Pb	0.000064	0.001922	0.000001	0.00000	0.000000	0.005971	0.000091	0.000027	0.000087	0.000093
Zu	0.003551	ns	ns	ns	ns	ns	ns	ns	ns	ns
Cu	0.022377	ns	ns		ns	ns	ns	ns		ns
Mg	ns		ns		ns	0.004041	ns	ns	ns	ns

Explanation: as in tab. 1.

Contemporary analytical methods make it possible to precisely determine the content of toxic elements in biological material, while environmental monitoring provides information on the distribution of contamination (26). Modern technologies are being developed, capable of successfully reducing heavy metal emissions of anthropogenic nature into the atmosphere, water and soil, which offers hope for a gradual cleansing of ecosystems. In the case of animal breeding, the most straightforward method for limiting excessive bio-accumulation is to change the direction of their use and systems of maintenance. Attempts are also being made to reduce the bio-accumulation of heavy metals in the organisms of animals by modifying their diets in such a way as to take advantage of antagonistic or synergistic interactions between their ingredients (1, 3). However, in order to build foundation for these attempts it is necessary to investigate physiological and biochemical mechanisms which take place in the organisms of animals at all stages of their functioning. Such was the purpose of the present experiment, aimed at evaluating the transfer of heavy metals and essential elements from the organism of the mother to its offspring via healthy and sick milk glands. In stage II, the mother sheep were administered a mixture of salts of Pb, Cd, Mg, Cu and Zn, which caused interactions between the toxic and essential metals, as illustrated by the content of these elements in the milk and blood of the mothers and in the blood of the lambs.

The favourable influence of these elements on the content of heavy metals in the blood of the animals was confirmed for both Pb and Cd. The most significant decrease in the content of Cd in the blood of the ewes was noted in sample '1' of stage II in both the healthy animals and those presenting subclinical mastitis. In animal organisms there is a very clear biochemical antagonism between Zn and Cd. As we already observed, this mechanism consists in the displacement of Cd by Zn in protein compounds. The author's research confirmed the theses put forward by Anke and Groppel (1) and by Groten et al. (7).

In the case of Pb, the antagonistic interaction between the bioelements proved even more effective. A decrease in the content of Pb was observed in the blood samples collected from the control and experimental ewes alike. After the animals were administered the mixture of salts of Pb, Cd, Mg, Cu and Zn, the Pb content in blood samples '1' and '2' was found to be smaller than in stage I. The highest decrease was observed in sample '1': from 209.92 μg/l to 62.68 μg/l in the control group, and from 314.49 μg/l to 62.21 μg/l in the experimental group. This effect was undoubtedly related to the antagonistic action of Zn and Cu against Pb. In experiments on rodents, it was demonstrated that an increase of the Cu content in their diet diminishes the absorption of Pb from the alimentary tract and reduces the Pb level in blood serum (3). The antagonism between Zn and Pb results from the mechanism of their absorption in the stomach and intestines, which is similar for both elements, as well as from their rivalry during transport through the albumin-lipid membranes (3 – quoted in Cerklewski). After enriching Pb-contaminated fodder in Zn, Cerklewski observed a drop in the concentration of Pb in the blood, liver and milk of female rats as well as a reduction in the toxic impact of Pb on the newborns. The attenuation of toxic effects of Pb through the administration of Zn was also demonstrated in works by Bafundo et al. (2) and Malinowska (15).

Among the bioelements administered in stage II of the present research, particularly noteworthy is Mg, whose content remained at a stable low level in all blood samples. The explanation of this fact is certainly related to interactions between the Pb, Cd and Mg; however, the levels observed in stage I were significantly higher, especially in sample '1'.

As in the case of blood, the milk of ewes also had a lower Pb content in stage II of the experiment: it was 4-5 times lower than in stage I. The same situation was observed in both groups of animals, which gives rise to the suggestion that the health status of milk glands does not influence the transfer of Pb into milk. Most likely, the mechanisms reducing the transfer of this element were based on the antagonism between Mg, Cu and Zn. The results of the author's research are not confirmed by works of Naresh et al. (20, 21). They concluded that subclinical mastitis significantly increases the concentration of Pb, Cu, Zn, and Cobalt (Co) in milk, and that the treatment of the udder with ascorbic acid significantly decreases the concentration of Pb in milk without influencing the Cd content.

In stage II of the research, administering the ewes with a mixture containing no only Cd and Pb but also Mg, Cu and Zn led to an evident increase in the content of the last three elements in milk. Actually, the Zn content in milk exceeded the norm, which is 5.0 mg/kg (24). This increase was observed in all samples in stage II, in healthy animals as well as those presenting subclinical inflammation of milk glands. The highest content of Zn in milk was noted in the group of experimental animals and did not exceed the value of 8.40 mg/kg. The level of Cu was also higher but did not exceed the norm in any of the samples (24). In stage II of the research, a higher level of Mg in milk was also ascertained, both in the healthy animals and in those presenting subclinical inflammation of the udder, which can be considered as a welcome phenomenon since this element is responsible for a number of metabolic functions, and its deficiency can lead to disorders in ruminants, including grass tetany. The highly significant reduction in the levels of Pb and Cu in the milk of ewes was confirmed by the fall in Pb and Cu content in the blood of the lambs of both groups. The content of the other elements remained close to the levels observed in stage I, which gives rise to the suggestion that the essential elements administered to the ewes have a favorable effect of on the content of toxic elements in the blood of their offspring.

Conclusion

The investigations did not reveal any significant influence of the health status of milk glands on the content of Pb and Cd in the blood of lambs. The extent to which toxic elements were transferred into the blood of the lambs was similar for the lambs originating from the healthy ewes and for those from the ewes with subclinical mastitis.

The administration of a mixture of toxic and essential elements to the mothers activated antagonistic reactions between the elements. The investigations demonstrated a beneficial influence of Mg, Zn and Cu on the content of Pb and Cd in the blood and milk of the mothers: the concentration of Pb in the milk of the ewes in stage II was 4-5 times lower than in stage I of the research. The decrease in the levels of Pb and Cd in the milk of the ewes, observed in stage II of the research, was confirmed by their reduced content in the blood of the lambs originating from both the healthy ewes and the ewes with subclinical mastitis.

References

1. *Anke M., Groppel B.*: Możliwości ograniczania szkodliwego wpływu miedzi, siarki, kadmu, molibdenu, cynku i niklu na zwierzęta gospodarskie. Mat. Konf. Ochrona środowiska a intensyfikacja produkcji zwierzęcej, Kraków 1985, p. 3-40.
2. *Bafundo K. W., Baker D. H., Fitzgerald P. R.*: Lead toxicity in chicks affected by excess copper and zinc and by Eimeria acervulina infection. Poult. Sci. 1984, 63, 1594-1603.
3. *Bodak E., Dobrzański Z.* (praca zbiorowa.): Ekotoksykologiczne problemy chowu zwierząt w rejonach skażeń metalami ciężkimi. Wyd. ELMA, Wrocław 1997.
4. *Bremmer I., Hoekstra W. G., Davies N. T., Young B. W.*: Effect of zinc status of rats on the synthesis and degradation-induced metallothioneins. Bioch. J. 1978, 174, 883-892.
5. *Dabeka R. W., Karpiński K. F., McKenzie A. D., Badjik C. D.*: Survey of lead, cadmium and fluoride in human milk and correlation of levels with environmental food factors. Food. Chem. Toxicol. 1986, 24, 913-921.
6. *Green M., Gruener N.*: Transfer of lead via placenta and milk. Res. Comm. Chem. Pathol. Pharmacol. 1975, 8, 735-538.
7. *Groten J. P., Sinkeldam E. J., Muys T., Luten J. B., Bladerenn P. J.*: Interaction of dietary Ca, Pb, Mg, Mn, Cu, Fe, Zn, and Se with the accumulation and oral toxicity of cadmium in rats. Food. Chem. Toxicol. 1991, 29, 249--258.
8. *Hayashi M., Ito O., Ohira S., Akuzawa J.*: Transfer of lead and cadmium from cow milk to butter. Bull. Environ. Contam. Toxicol. 1982, 29, 658-661.
9. *Kehoe R. A., Thaman F., Cholak J.*: On the normal absorption and excretion of lead. IV. Lead absorption and excretion in infants and children. J. Ind. Hyg. 1988, 5, 301-305.
10. *Keller C. A., Doherty R. A.*: Bone lead mobilization in lactating mice and lead transfer to suckling offspring. Toxicol. Appl. Parmacol. 1980, 55, 220--228.
11. *Keller C. A., Doherty R. A.*: Lead and calcium distributions in blood, plasma, and milk of the lactating mouse. J. Lab. Clin. Med. 1980, 5, 81-89.
12. *Kostial K.*: Specific features of metal absorption in suckling animals, [in:] Clarkson T. W., Nordberg G. F., Sager P. R. (Eds.): Reproductive and Developmental Toxicity of Metals. Plenum Press, New York and London 1983, 727-747.
13. *Lacey R. F., Moore M. R., Richards W. N.*: Lead in water, infant diet and blood: the Glasgow duplicate diet study. Sci. Tot. Environ. 1985, 41, 235-257.
14. *Lorenzo A. V., Gewirtz M., Maher C., Davidowski L.*: The equilibrium of lead between blood and milk of lactating rabbits. Life Sci. 1997, 21, 1679-1684.
15. *Malinowska A.*: Synergistyczne i antagonistyczne działanie niektórych makro- i mikroelementów u trzody chlewnej. Medycyna Wet. 1998, 54, 242--245.
16. *Malinowski E., Krzyżanowski J., Szaluś J., Moulallem H.*: Próby zachowawczego leczenia ostrych zapaleń wymion u owiec. Medycyna Wet. 1985, 41, 521-522.
17. *Malinowski E., Krzyżanowski J., Wawron W., Głuszak J., Orlik S.*: Lecznicze i profilaktyczne wprowadzenie antybiotyków do wymion owiec po zakończeniu laktacji. Medycyna Wet. 1985, 41, 410-411.
18. *Mamihira D., Saldivar, Pustilnik N., Carreón, Salinas M. E.*: Lead in human blood and milk from nursing women living near a smelter in Mexico city. J. Toxicol. Environ. Health 1993, 38, 225-232.
19. *Moore M. R., Goldberg A., Pocock S. J., Meredith A., Steward I. M., MacAnespie H., Lees R., Low A.*: Some studies of maternal and infant lead exposure in Glasgow. Scot. Med. J. 1982, 27, 113-122.
20. *Naresh R., Dwivedi S. K., Swarup D., Dey S.*: Lead cadmium concentrations in milk and blood of Indian cows with mastitis. Vet. Hum. Toxicol. 1999, 41, 392-393.
21. *Naresh R., Dwivedi S. K., Swarup D., Patra R. C.*: Effect of ascorbic acid on milk lead and cadmium level on subclinical and clinical cases of mastitis. Bull. Environ. Contam. Toxicol. 2003, 71, 899-904.
22. *Ong C. N., Phoon W. O., Law H. Y., Tye C. Y., Lim H. H.*: Concentrations of lead in maternal blood, cord blood, and breast milk. Arch. Dis. Child. 1985, 60, 756-759.
23. *Palminger-Hallén I.*: Lead excretion in breast milk and transfer to suckling offspring: Comprehensive summaries of Uppsala Dissertations from the Faculty of Pharmacology 134. Acta Universitatis, Uppsala 1995.
24. Rozporządzenie Ministra Zdrowia z dnia 13 stycznia 2003 r. w sprawie maksymalnych poziomów zanieczyszczeń chemicznych i biologicznych, które mogą znajdować się w żywności, składnikach żywności, dozwolonych substancjach dodatkowych, substancjach pomagających w przetwarzaniu albo na powierzchni żywności. Dz. U. z 2003 r. nr 37, poz. 326.
25. *Tachon P., Laschi A., Briffaux J. P., Brain G.*: Lead poisoning in monkeys during pregnancy and lactation. Sci. Tot. Environ. 1983, 30, 221-229.
26. *Wałkuska G.*: Wykorzystanie zająca (Lepus europaeus Pallus) do oceny stopnia zanieczyszczenia środowiska związkami ołowiu, kadmu, cynku i miedzi w makroregionie środkowowschodnim Polski. Rozpr. Nauk. AR (219), Rozp. hab. Wydawnictwo AR, Lublin 1999.
27. *Webb M., Holt D.*: Endogenous metal binding proteins in relation to the differences in absorption and distribution of mercury in newborn and adult rats. Arch. Toxicol. 1982, 49, 237-245.

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