Biol. Stud. 2022; 16(4): 45–58 • DOI: https://doi.org/10.30970/sbi.1604.697
www.http://publications.lnu.edu.ua/journals/index.php/biology

UDC: 636.92.053.112.385.4

ZINC CITRATE INFLUENCE ON THE CONCENTRATION OF SOME MACRO- AND MICROELEMENTS IN RABBIT BODY TISSUES

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Boiko, O., Lesyk, Ya., Bashchenko, M., Honchar, O., Denys, H., Grabovska, O., & Luchka, I. (2022). Zinc citrate influence on the concentration of some macro- and microelements in rabbit body tissues. *Studia Biologica*, 16(4): 45–58. doi:10.30970/sbi.1604.697

Background. Some of the humanity's problems in the 21st century are related to insufficient mineral nutrition according to the World Health Organization. The reason for this conclusion is not in the amount of mineral substances supplied with food, but in their bioavailability in the body. The problem of rabbit high-quality mineral nutrition is not solved during industrial maintenance. Research on the impact of organic compounds of trace elements on the human and animal body has intensified over the last decade. Studies show the effectiveness of the use of organic compounds of microelements with unique physiological properties to penetrate the cell and exert an activating effect on the course of biochemical reactions, which positively affects the whole organism. However, the physiological effect occurs under the condition of receiving and assimilation of organic compounds of trace elements in optimal amounts. Therefore, the main task of this research was to study the effect of the investigated doses of zinc citrate, which was fed in rabbits for 36 days after weaning to assess the change in the content of minerals in the tissues of their body.

Materials and Methods. Studies were conducted on 16 rabbits that were close by clinical and visual indicators aged 40 days from birth, kept in a laboratory room of a research institution equipped with mesh industrial cages for rabbits. Rabbits of the control group were kept with free access to complete nutrient and mineral supplementation in feed and water. The animals were kept separately in cages and an appropriate amount of zinc citrate was added to the daily amount of water (100 mL) every day.

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Rabbits of this age drink an average of 100 mL of water per day. Rabbits of study groups I, II, and III used the same feeding as in the control, in addition, for 24 hours, zinc citrate was additionally used with water in the amount of: I – 0.25; II – 0.50; III – 0.75 mg Zn/kg of body weight. The comparative period was 10 days, the experimental period was 36 days. On day 36 of the study, animals of all groups were euthanized; their blood and tissues: liver, kidney, ribeye, spleen, and hair from the thigh area of rabbits were taken to determine the content of mineral elements using an atomic absorption spectrophotometer.

Results. Feeding zinc citrate with water in the amount of 0.25 mg Zn/kg of body weight was marked by a probable increase in the content of Co and Cu (P <0.05) in the blood. Administration of zinc citrate in the amount of 0.50 mg Zn/kg of body weight was characterized by a probable increase in Zn (P <0.001), Co (P <0.001), Fe (P <0.05), Cu (P <0.05) in the blood; the level of Z (P <0.05), Cr (P <0.05), Co (P <0.01), Fe (P <0.05), Cu (P <0.01) in the liver; Fe (P <0.05) and Cu (P <0.05) in the spleen, Zn (P <0.05) in muscle and hair compared to control. The use of zinc citrate at the rate of 0.75 mg Zn/kg of body weight induced the most probable changes: the content of Zn (P <0.01) in the blood, liver (P <0.05), spleen (P <0.01), muscle (P <0.05) and hair (P <0.01), Cr in the liver (P <0.05), Co in the blood (P <0.01), liver (P <0.01), spleen (P <0.01), Fe (P <0.01) and Cu (P <0.05) in the blood, liver (P <0.05–0.01), kidneys (P <0.05–0.01), Fe in the spleen (P <0.01) and muscle (P <0.05) compared with the control group.

Conclusions. Additional administration of zinc citrate (0.25 mg Zn/kg body weight) with water for 36 days was marked by the smallest changes in the studied mineral substances concentration of rabbits' tissues, with the exception of an increase in the Co and Cu blood content. With an increase in the daily amount of zinc citrate (0.50 and 0.75 mg Zn/kg body weight), the concentration of Zn, Co, Fe, and Cu in the blood and liver tissue mainly increased*,* while less prominent changes were noted in the tissue of the spleen and kidneys compared to the control group. Macro- and microelements concentration changes may indicate a more pronounced effect of zinc citrate depending on the applied amount, in particular, a larger amount (0.75 mg Zn/kg body weight) induced the greatest probable increase in the studied microelements, with the exception of Mg and Mn in the rabbits' body tissues.

Keywords: rabbits, body tissues, zinc citrate, macroelements and microelements

INTRODUCTION

Zinc is an important trace element for the overall functioning of the animal body. It performs three main biological functions, namely it plays the catalytic role in the functioning of more than 300 enzymes, as well as the structural and regulatory role (Reda *et al*., 2020). In addition, it affects the immune system, nucleic acid synthesis, cell proliferation, protein synthesis, protein and carbohydrate metabolism, as well as activates the enzyme activity of the body (Geetha *et al*., 2020). Studies have established a dose-dependent effect of **organic compounds** with zinc oxide on the growth rates and physiological status of cattle and poultry (Mahmoud *et al*., 2020). Zinc deficiency affects the secretion of thymulin and the formation of T cells in the thymus, which leads to a violation of its physiological function and adversely affects the immune system (Mohamed *et al*., 2019). Zinc, as an antioxidant involved in important mechanisms of protection against reactive oxygen species, it is a cofactor of the superoxide dismutase enzyme which performs an important function of protecting the body from free radicals (Nabi *et al*., 2020).

It should be noted that zinc deficiency in animals leads to low circulation of insulin-like factor-1, which is the most important endocrine mediator of somatotropic hormone and is synthesized in the liver. It is produced by liver hepatocytes in response to stimulation of their somatotropin receptors depending on the physiological level of zinc in the body (Li *et al*., 2021).

Innovations in animal feeding involve the introduction of advanced technologies aimed at increasing the efficiency of animal husbandry by improving the health of animals and hence the quality of their products (Alagawany *et al*., 2018; Alagawany *et al*., 2020). The diet and the type of feed and additives used play an important role in the development of animal husbandry technology (Al-Nuairi *et al*., 2020). Currently, modern methods of bioengineering and genetic engineering are used in animal husbandry to develop organic compounds of trace elements, including the essential element zinc (Attia *et al*., 2019). Modern technologies for the production of organic additives offer new solutions for the transformation of biosystems and a wide potential for improving animal husbandry systems (Soren *et al*., 2018).

Recently, the development of methods for developing organic additives has progressed in various scientific fields (El-Saadony *et al*., 2020). Organic trace elements interact more effectively with inorganic substances in the animal body due to high catalytic efficiency and strong adsorption capacity. Organic compounds of trace elements can actively penetrate through the microvilli of the small intestine, and then spread into the blood and internal organs (El-Rayes *et al*., 2019; El-Moghazy *et al*., 2019).

A study on New Zealand white rabbits evaluated the modulating effects of zinc oxide organic additives on performance, blood biochemical parameters, and meat quality. The results showed that the use of zinc oxide at a dose of 80 mg/kg in the diet improved the performance and the quality of rabbit meat. The obtained results indicate an increase in bioavailability and improved absorption of zinc oxide, compared with inorganic sources of zinc. It was established that zinc oxide can change the amount of minerals due to its high bioavailability (Abdel-Wareth *et al*., 2022).

The addition of zinc to the diet of rabbits contributes to its deposition in meat, which improves its quality characteristics and increases the biological value of muscle tissue and better satisfies human needs in Zn. In addition, a balanced content of trace elements in the muscle tissue of rabbits can increase the shelf life of meat (Luis-Chincoya *et al*., 2021). Most studies have shown minor positive results of the application of zinc oxide, however, the zinc oxide supplement in the diet in an amount of 100 mg/kg of feed improved rabbit performance, meat quality, and antioxidant capacity during heat stress (Hassan *et al*., 2021).

The addition of zinc oxide to the diet increased ($P < 0.05$) the performance parameters of serum lipids, high-density lipids, and immunoglobulins in rabbits. The study concluded that the use of zinc oxide improved the performance, blood lipid profile, immunity, and antioxidant status ($P < 0.05$) of young rabbits under heat stress (Kamel *et al*., 2020).

However, some studies did not show differences in the bioavailability of zinc between organic and inorganic sources used in the diet of meat breeds rabbits. According to some researchers, this may be due to individual doses of the supplement not being sufficiently calculated for their diet. The conducted study showed a positive impact of some indicators and triggered new interest to performing in-depth studies using organic and inorganic additives depending on the optimal dose in the diet (Čobanová *et al*., 2018).

Previous studies on weaned rabbits feeding on the diet of silicon citrate (Lesyk *et al*., 2020) and zinc citrate at different doses (Boiko *et al*., 2020a; Boiko *et al*., 2020b), have demonstrated a positive effect on the hematological (Lesyk *et al*., 2019) and biochemical parameters of blood and the performance of their body. Given the above, the main task of the experiment was to analyze the changes in the content of individual minerals in the rabbit body after drinking water with zinc citrate for 36 days.

MATERIALS AND METHODS

The study was performed in a laboratory room of a research institution equipped with mesh industrial cages for keeping rabbits. All the manipulations with animals were carried out in accordance with the International Convention on the Protection of Animals and the Law of Ukraine "On Protection of Animals from Cruelty" (the Minutes of the bioethical examination commission meeting of the Institute of Animal Biology NAAS No. 75/a dated April 10, 2019). Young rabbits aged 40 days, which were physiologically healthy in terms of clinical and visual indicators with the same body weight ranging from 1.2 to 1.4 kg, were selected for the experiment. They were then divided by gender (equal number of females and males) into separate groups of 4 rabbits each. The animals were kept separately in cages and an appropriate amount of zinc citrate was added to the daily amount of water (100 mL) every day. Rabbits of this age drink an average of 100 ml of water per day. The young rabbits in the control group consumed balanced nutrient and mineral granular compound feed, and water without restriction. Rabbits of study groups I, II, and III consumed the same feed as in control, in addition, for 24 hours, zinc citrate was added to water at doses I – 0.25; II – 0.50; III – 0.75 mg Zn/kg of body weight. The zinc citrate solution was obtained from the manufacturer "Nanomaterials and Nanotechnologies", Kyiv, with the main parameters – 1.0 g/L; pH 1.38. The pH level was examined in the water provided to the rabbits; it remained unchanged due to the small amount of the additive introduced to the daily norm. The comparative period was 10 days, the experimental period was 36 days. On day 36 of the study, animals of all groups were euthanized. Their blood and tissues, namely liver, kidneys, ribeye, spleen, and hair were taken to determine the mineral elements content using an atomic absorption spectrophotometer (Vlislo *et al*., 2012). The selection of the listed tissues of the rabbit body will show the effect of zinc citrate on the concentration of the studied macro- and microelements at the level of the whole body, and will determine the organs most sensitive to the introduction of the microelement. All manipulations with experimental animals were carried out in compliance with the rules of the European Convention for the Protection of Vertebrate Animals used for Experimental and Other Scientific Purposes (Official Journal of the European Union L276/33, 2010).

Sampled tissues – blood in the amount of 20 ml and tissues of parenchymal organs, muscle, and hair cover from 5 to 20 g – were dehydrated in dry heat at a temperature from 100 to 105 °C. Then in a muffle furnace at high 500−550 °C stepwise temperatures, the organic amount in tissue samples was isolated until white or pale pink ash was obtained. The obtained sample was then adsorbed into 20 mL of 10% hydrochloric acid, after which it was purified from the precipitate by filtering in the prepared tubes. After that, the spectrum of the corresponding element was determined in the fire flame, depending on the wavelength, similarly to the lamp introduced into the atomic absorption spectrophotometer SF-115 PC with a computer program that calculated the concentrations of the element in mg/kg of tissue, taking into account the weight of the tissue and the degree of dilution.

In addition, the concentration of Cr, Co, Zn, Fe, Cu, Mg, Mn was determined in the granulated compound feed. For the study, 10 average feed samples of 10 g each were selected, dried in an oven at a temperature of 100 to 105 °C, then heated in a muffle furnace at a high temperature of 500−550 °C until white or coarse ash was obtained. Then the obtained sample was adsorbed in 20 ml of 10% hydrochloric acid, after which it was cleaned of sediment by filtering into prepared test tubes. After that, the spectrum of the corresponding element in the flame of the fire was determined depending on the wavelength, similar to the lamp inserted into the atomic absorption spectrophotometer SF-115 PC with a computer program that calculated the concentration of the element in mg/kg. tissues, taking into account the weight of the feed and the degree of dilution. The mathematical processing of the study results was developed statistically using the software package Statistica 7.0 software (Stat Soft, Tulsa, USA). Differences between values in the control and experimental groups were determined using ANOVA, where the differences were considered significant at $P < 0.05$.

RESULTS AND DISCUSSION

Many researchers noted that providing the body of modern fast-growing breeds of rabbits with easily available and optimal amounts of minerals will increase the profitability of industrial rabbit farming. Recently, there has been an increasing interest in the use of the newest methods to raise the effectiveness of micronutrients in rabbit diets, which can be used as a substitute for traditional inorganic sources of minerals in animal feed (Mohamed *et al*., 2019; Nabi *et al*., 2020; Li *et al*., 2021).

Although the micronutrient zinc plays an important role in the synergy of other minerals and is involved in the activation of many enzymes, its action depends on the amount used in the diet, in addition, its digestibility through the mechanisms of transport in the mucous membrane of the small intestine is important. Determination of the macro- and microelements concentration in the granular feed testifies the sufficient physiological level of most of the studied elements, namely chromium, cobalt, copper, and magnesium (**Table**), in contrast to the slightly lower level of zinc, iron, and manganese.

The concentration of mineral elements in granulated feed, mg/kg of natural mass (M±m, n = 10)

Mineral elements	Composite feed
Cr	0.24±0.18
Co	0.32±0.02
Zn	35.1±0.46
Fe	88.3±1.10
Cu	10.1±0.22
Mg	3.0±0.18
Mn	10.2±0.19

Obviously, the additive used does not fully provide the needed amount of these trace elements in granular feed. Besides, over time they get oxidized and their effectiveness decreases, which is discussed in various forums. Thus, the application of new organic compounds containing trace elements is relevant and necessary to solve this problem in industrial livestock. It is very important in rabbit breeding, especially when breeding hybrids, where a full balance of mineral nutrition significantly affects the development of an organism and livestock preservation.

Generalization of the obtained concentration of the studied minerals indicates their decrease or increase depending on the amount of zinc citrate used, which was fed in rabbits. Macro- and microelements concentration in rabbit blood and some organs of the body under the action of zinc citrate are presented in **Figures 1–7.**

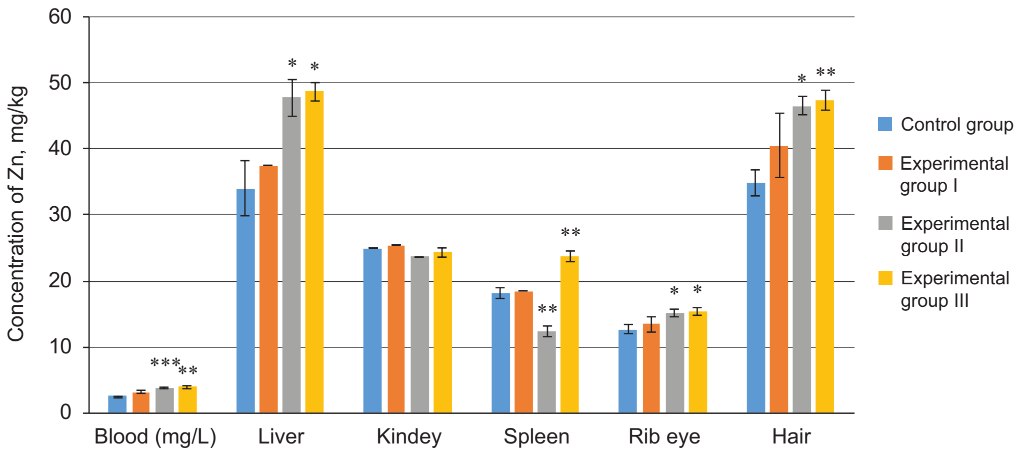

Fig. 1. Concentration of Zn in rabbit blood and some organs
Note: statistically significant differences were taken into account compared with the control group: * – P <0.05; ** – P <0.01; *** – P <0.001; C – control group, E-I, E-II, E-III – experimental groups

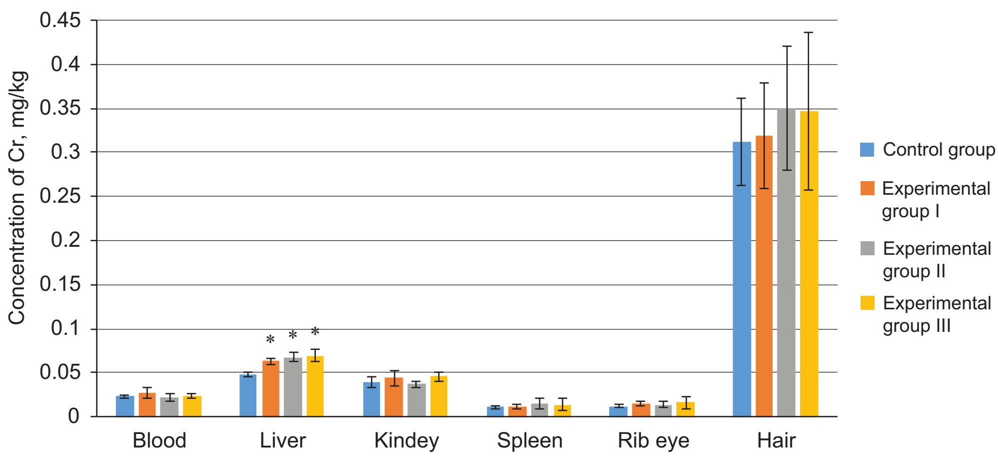

Fig. 2. Concentration of Cr in rabbit blood and some organs
Note: statistically significant differences were taken into account compared with the control group: * – P <0.05; C – control group; E-I, E-II, E-III – experimental groups

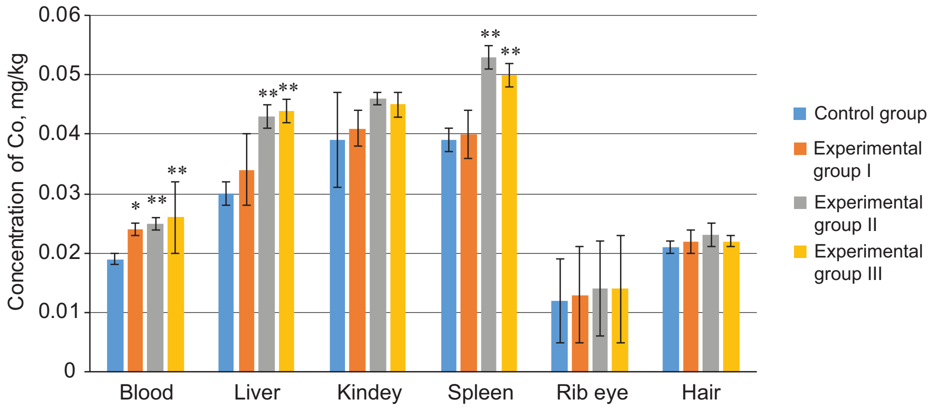

Fig. 3. Concentration of Co in rabbit blood and some organs
Note: statistically significant differences were taken into account compared with the control group: * – P <0.05; ** – P <0.01; C – control group; E-I, E-II, E-III – experimental groups

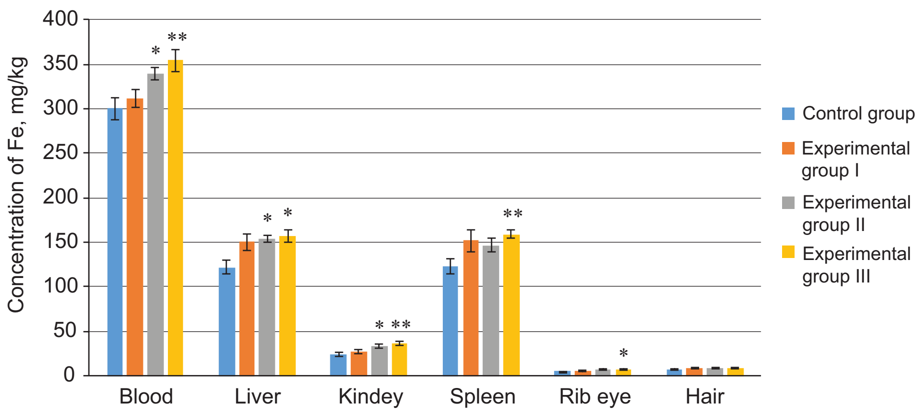

Fig. 4. Concentration of Fe in rabbit blood and some organs
Note: statistically significant differences were taken into account compared with the control group: * – P <0.05; ** – P <0.01; C — control group; E-I, E-II, E-III – experimental groups

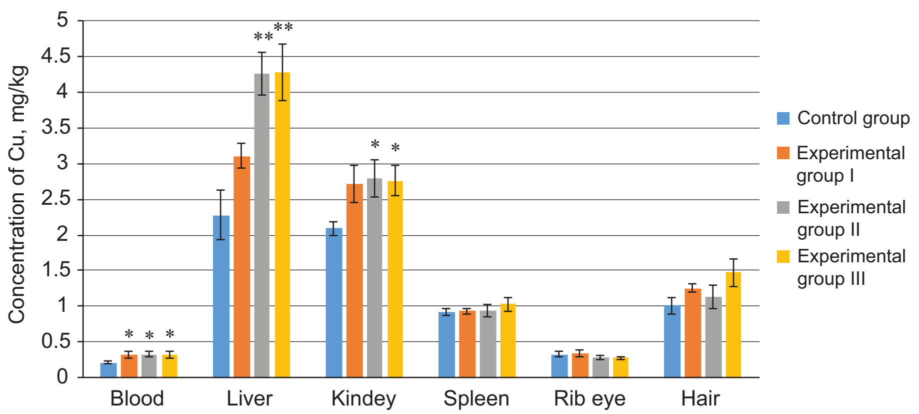

Fig. 5. Concentration of Cu in rabbit blood and some organs
Note: statistically significant differences were taken into account compared with the control group: * – P <0.05, ** — P <0.01; C – control group; E-I, E-II, E-III — experimental groups

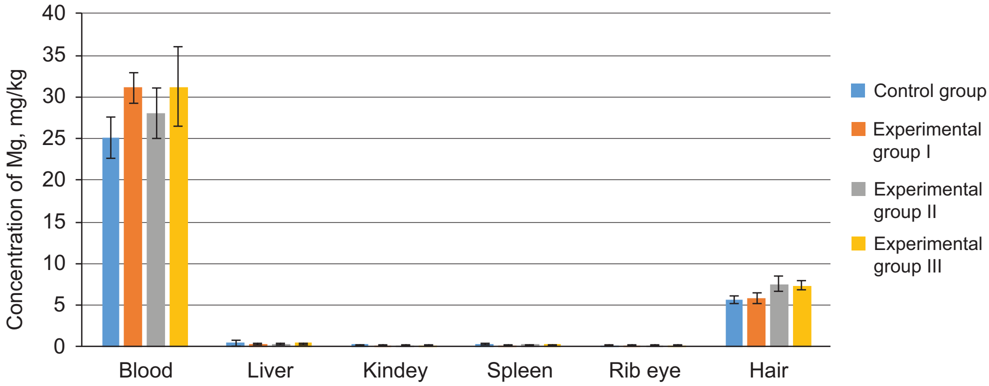

Fig. 6. Concentration of Mg in rabbit blood and some organs
Note: C – control group; E-I, E-II, E-III – experimental groups

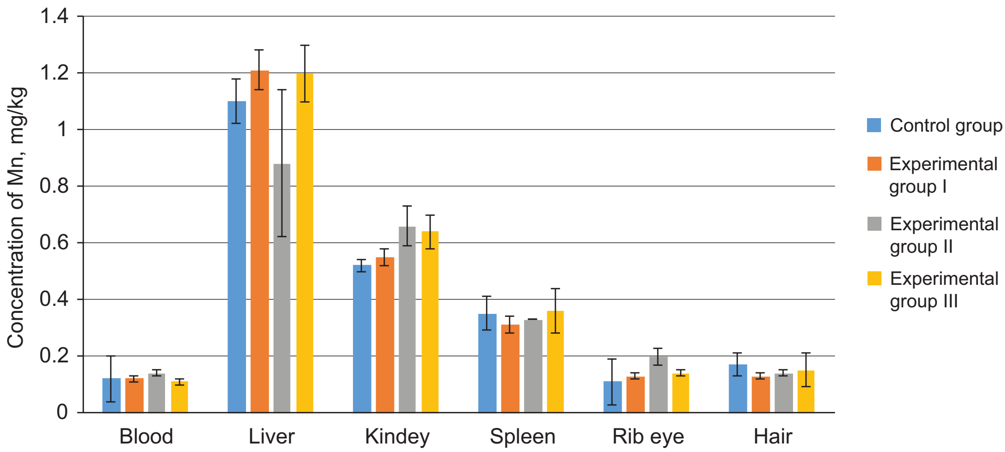

Fig. 7. Concentration of Mn in rabbit blood and some organs
Note: C – control group; E-I, E-II, E-III – experimental groups

It should be noted that the application of the minimum amount of zinc citrate (0.25 mg Zn/ kg of body weight) in the study caused a significant increase in the concentration of Co and Cu only ($P < 0.05$) in the blood of rabbits after 36 days of use of the supplement compared to the control. Experimentally, there was an increase in other test elements in the tissues of the rabbits' bodies in group I, but these differences were not indicated in the parameters of changes to the control, which would be determined by the probability.

A higher amount of zinc citrate (0.50 mg Zn/kg body weight) fed to group II rabbits contributed to slightly greater likely differences with control, in particular, increased concentrations of Zn ($P < 0.001$), Co ($P < 0.01$), Fe ($P < 0.05$), and Cu ($P < 0.05$) in rabbit blood. The obtained results of the more pronounced synergistic effect of bioavailable zinc may indicate the features of organic compound of a trace element exposure in the body of rabbits after weaning. Generalizations support the hypothesis of more active action of a greater amount of supplement in the diet, compared to a lesser one. In addition, the concentration of zinc in the blood did not change significantly as a result of the application of a higher and lower doses of zinc, which can indicate a balance of the processes of absorption of this trace element in the body of rabbits and a significantly higher need for its diet.

In our opinion, the results regarding the trace elements concentration found in the blood of rabbits that were given the highest dose of zinc citrate under study (0.75 mg Zn/kg of body weight), are interesting. In particular, significantly higher changes in the blood of rabbits were in the content of Zn ($P < 0.01$), Co ($P < 0.01$), Fe ($P < 0.01$), and Cu ($P < 0.05$). The obtained probable differences in the effect of zinc citrate affected the same trace elements as in group II compared to the control. The results obtained may suggest the same reinforcing, and therefore the synergistic effect of the applied compound on the increase in the concentrations of Zn, Co, Fe, and Cu in the body of rabbits.

Statistical calculation of the research results of the micro- and macroelements concentration in vital parenchymal organs, the ribeye, and hair cover of rabbits convincingly indicate a pronounced activating effect of the supplement, depending on the dose, on the studied levels of microelements. The liver in rabbits is the central organ of metabolism and a marker of nutrient intake in their body, and the content of minerals in its tissue may indicate the activity of metabolism in this parenchymal organ. Zn ($P < 0.05$), Cr ($P < 0.05$), Co ($P < 0.01$), Fe ($P < 0.05$), and Cu ($P < 0.01$) concentrations significantly increased in the liver of rabbits fed with zinc citrate at the medium dose (0.50 mg Zn/kg body weight) compared to rabbits that did not receive supplements. In another parenchymal organ – the spleen, a higher level of Fe ($P < 0.05$) and Cu ($P < 0.05$) was noted, in addition, the concentration of Zn ($P < 0.05$) in the tissues of the ribeye and hair was likely to increase. The application of a higher dose of zinc citrate compared to the first group of animals showed a higher concentration of zinc in the liver tissue, muscle, and hair, which can indicate the accumulation of this element in them due to better digestibility in the body and the stimulating effect of the level of Cr, Co, Fe, and Cu.

The use of the highest dose of zinc citrate (0.75 mg Zn/kg body weight) in the diet of rabbits showed the most significant changes in the blood and, as a result, in the studied organs, muscle tissue, and hair of rabbits. Significant concentrations of Cr ($P < 0.05$), Co ($P < 0.01$), Fe ($P < 0.05$) and Cu ($P < 0.01$) were observed in liver tissue compared to the control. In the spleen, the activating effect of zinc citrate on the content of Co ($P < 0.01$) and Fe ($P < 0.05$), in the kidney tissue Fe ($P < 0.01$), and the ribeye ($P < 0.05$) was recorded compared to rabbits that were not fed the organic supplement.

Analyzing the results of the experimental work, we found a different effect of zinc citrate on the change in the concentration of the studied macro- and microelements in rabbit tissues. It should be noted that an increase in the dose of zinc citrate had a greater effect on the activation of trace elements in the studied rabbit tissues. On the one hand, this may be due to the wide range of inorganic zinc introductions into the diet of rabbits, thus, a greater number had a higher modeling effect. In addition, the results obtained indicate an increase in bioavailability and an improvement in the absorption of organic zinc, compared with its inorganic sources, since the organic compound can change the accumulation of microelements due to its high bioavailability. Zinc is a vital element playing an important role in the metabolism of carbohydrate and protein synthesis, as well as lipids, because of its important role in the action of enzymes as a component of several metalloenzymes that are involved in digestion and absorption of nutrients (De Blas & Wiseman, 2020).

The application of zinc citrate depending on the dose was marked by the synergistic effect of most of the studied trace elements, but we observed no typical changes in our work. This applies to the established antagonism between copper and zinc (De Blas & Wiseman, 2020), we have not confirmed such an impact, since the application of zinc citrate at a dose of 0.50 and 0.75 mg Zn/kg of body weight contributed to a likely increase in the content of Zn and Cu in the blood and liver. This is obviously due to the action of the bioavailable zinc compound on the course of mineral metabolism processes in the digestive system and the transport system and cells of the studied rabbit organs. Therefore, organic zinc is supposed to be efficient in small quantities, provide better bioavailability, and constantly interact with other elements when fed as an alternative to conventional sources (Hassan *et al.,* 2017).

Unlike the synergism of copper and zinc, it is known from literature about manganese's antagonism regarding the concentration of iron and zinc (De Blas & Wiseman, 2020). It should be noted that the statistical calculation of the results showed a higher content of iron and zinc and a lower content of manganese. The partial change of the obtained research results due to synergism and antagonism can be associated with the peculiarities of the action of the organic compound which enhances their effect through transport pathways in the biological membranes of the cell (El-Saadony *et al*., 2020).

Thus, from the obtained results of the mineral elements concentration in the body tissues of rabbits under the influence of zinc citrate, some differences in the effect on the studied elements were revealed. A special effect was noted, depending on the dose of zinc citrate used, which was more pronounced in rabbits of study group III, to which the largest amount of the studied mineral substances was applied. In addition, zinc citrate effect on the concentration of Cr, Co, Fe, and Cu in rabbit tissue was established compared to the control group of animals in which their levels were lower.

CONCLUSIONS

1. Additional administration of zinc citrate to water for 36 days at the rate of 0.25 mg Zn/kg body weight was marked by the smallest changes in the studied mineral substances concentration in the rabbits' body tissues, with the exception of the Co and Cu content increase in the blood.
2. With an increase in the daily amount of zinc citrate (0.50 and 0.75 mg Zn/kg body weight), the Zn, Co, Fe, and Cu concentration in the blood and liver tissue most likely increased, while less prominent changes were noted in the spleen and kidneys tissue, muscle and bones compared to the control group.
3. Changes in the individual macro- and microelements concentration may indicate a more pronounced effect of zinc citrate depending on the applied amount, in particular, a larger amount of 0.75 mg Zn/kg of body weight induced the greatest probable increase of the investigated microelements, with the exception of Mg and Mn in body tissues of rabbits.

COMPLIANCE WITH ETHICAL STANDARDS

Conflict of Interest: There were no any commercial or financial relationships that could be interpreted as a potential conflict of interest.

Human Rights: The article does not contain any investigations with human subjects.

Animal studies: All international, national and institutional guidelines for the care, maintenance and use of laboratory animals were followed.

AUTHOR CONTRIBUTIONS

Conceptualization, [B.O.V.]; methodology, [B.M.I.]; investigation, [D.H.H]; data analysis, [L.Ya.V., G.O.S.]; writing – original draft preparation, [L.Ya.V.]; writing – review and editing, [H.O.F.]; L.I.V.]; visualization, [L.Ya.V., L.I.V.]; supervision, [G.O.S. [D.H.H]; [O.V.T.]; project administration, [B.O.V., H.O.F.]; funding acquisition, [–].

All authors have read and agreed to the published version of the manuscript.

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ВПЛИВ ЦИНКУ ЦИТРАТУ НА КОНЦЕНТРАЦІЮ ОКРЕМИХ МАКРО- І МІКРОЕЛЕМЕНТІВ У ТКАНИНАХ ОРГАНІЗМУ КРОЛИКІВ

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Обґрунтування. За даними Всесвітньої організації охорони здоров'я, у XXI ст. проблема людства пов'язана з недостатнім мінеральним живленням. Причина такого висновку полягає не у кількості надходження мінеральних речовин із продуктами харчування, а у їхній біодоступності в організмі. За промислового утримання проблема якісного мінерального живлення кроликів невирішена. За останнє десятиліття збільшилися дослідження з вивчення впливу органічних сполук мікроелементів на організм людини й тварин. Результати експериментів доводять ефективність застосування органічних сполук мікроелементів, які мають унікальні фізіологічні властивості проникати у клітину та здійснювати активуючий вплив на перебіг біохімічних реакцій, що позитивно позначається на цілому організмі. Однак фізіологічна дія відбувається за умови надходження й засвоєння оптимальних їхніх кількостей. Тому основною задачею проведеного експерименту будо вивчити вплив досліджуваних доз цинку цитрату, який випоювали впродовж 36 діб кроликам після відлучення, для аналізу зміни вмісту макро- і мікроелементів у тканинах їхнього організму.

Матеріали та Методи. Дослідження проведені на 16 кроликах, близьких за клінічними та візуальними показниками віком 40 діб від народження, яких утримували в обладнаному сітчастими промисловими клітками для кроликів лабораторному приміщенні наукової установи. Кроленят контрольної групи утримували з вільним доступом до повнораціонного за поживними та мінеральними речовинами комбікорму й води. Кроликам I, II і III дослідних груп використовували годівлю таку як у контролі, крім цього, впродовж 24 годин додатково з водою застосовували цинку цитрат у кількості: I – 0,25; II – 0,50; III – 0,75 мг Zn/кг маси тіла. Підготовчий період становив 10 діб, експериментальний – 36 діб. На 36 добу дослідження тварин усіх груп піддавали евтаназії, проводили забір крові та тканин (печінки, нирок, найдовшого м'яза спини, селезінки та волосяного покриву зі стегнової ділянки) для визначення вмісту мінеральних елементів на атомно-абсорбційному спектрофотометрі.

Результати. Додаткове застосування з водою цинку цитрату у кількості 0,25 мг Zn/кг маси тіла позначилося вірогідним підвищенням вмісту Co та Cu (P <0,05) у крові. Застосування цинку цитрату в кількості 0,50 мг Zn/кг маси тіла характеризувалося вірогідним підвищення вмісту Zn (P <0,001), Co (P <0,001), Fe (P <0,05), Cu (P <0,05) у крові; у печінці рівня Zn (P < 0,05), Cr (P <0,05), Co (P <0,01), Fe (P <0,05), Cu (P <0,01); Fe (P <0,05) та Cu (P <0,05) у селезінці, у м'язі та шерсті Zn (P <0,05) порівняно з контролем. Використання цинку цитрату з розрахунку 0,75 мг Zn/кг маси тіла позначилося найбільшими вірогідними змінами: вмісту Zn (P <0,01) у крові, печінці (P <0,05), селезінці (P <0,01), м'язі (P <0,05) та шерсті (P <0,01), Cr у печінці (P <0,05), Co у крові (P <0,01), печінці (P < 0,01), селезінці (P <0,01), Fe (P <0,01) і Cu (P <0,05) у крові, печінці (P <0,05–0,01), нирках (P <0,05–0,01), Fe у селезінці (P <0,01) та м'язі (P <0,05) порівняно з контрольною групою.

Висновки. За додаткового введення до води цитрату цинку (0,25 мг Zn/кг маси тіла) протягом 36 діб спостерігали найменші зміни концентрації досліджуваних мінеральних речовин у тканинах кроликів, за винятком підвищення вмісту Co та Cu у крові. За умови збільшення добової норми цитрату цинку (0,50 та 0,75 мг Zn/кг маси тіла) концентрація Zn, Co, Fe та Cu у крові та тканині печінки швидше за все підвищувалася, тоді як у тканині селезінки, нирок спостерігали менші зміни порівняно з контрольною групою. Зміни концентрації макро- та мікроелементів можуть свідчити про більш виражену дію цитрату цинку залежно від застосованої кількості, зокрема, більша кількість (0,75 мг Zn/кг маси тіла) спричиняла максимальне вірогідне збільшення досліджуваних мікроелементів, за винятком Mg і Mn у тканинах організму кролика.

Ключові слова: кролики, тканини організму, цинку цитрат, макроелементи, мікроелементи

Received / Одержано	Revision / Доопрацьовано	Accepted / Прийнято	Published / Опубліковано
18 November, 2022	22 December, 2022	26 December, 2022	28 December, 2022