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ASSESSMENT OF ANTIOXIDANT STATUS OF RATS AT THE BACKGROUND OF CONSUMPTION OF SPECIALIZED CHOCOLATE WITH LEAD ACETATE EXPOSURE

This article presents the results of experimental research on the assessment of the antioxidant status of animals consuming specialized chocolate developed from mare's milk, enriched with resveratrol and vitamin E. The study demonstrated that after 30 days of intragastric lead acetate administration, rats showed an activation of lipid peroxidation processes in their blood serum. This was accompanied by the accumulation of both primary and secondary products—malondialdehyde and diene conjugates—as well as a decrease in vitamin E content and total antioxidant activity in the blood.

Excessive accumulation of peroxidation products was accompanied by increased catalase activity and decreased superoxide dismutase activity. It is noteworthy that all observed changes in the mentioned indicators were statistically significant. The reduction in antioxidant status highlighted the need to enrich the diet of animals under lead intoxication conditions with products containing high levels of antioxidants and antioxidant substances.

In this study, the effect of specialized chocolate enriched with mare's milk, resveratrol, and vitamin E on the antioxidant status of animals exposed to toxic lead acetate administration was evaluated. After 30 days of the experimental period, the consumption of 5 grams of specialized chocolate per day by the rats was found to improve their antioxidant status. This improvement was reflected by a reduction in lipid peroxidation products in the blood serum, increased superoxide dismutase activity, decreased catalase activity, and higher levels of vitamin E and total antioxidant activity in the serum.

The obtained results indicate the beneficial effect of the chocolate on the processes of lipid peroxidation and antioxidant defense, supporting its potential use for preventive purposes in cases of lead salt poisoning.

Keywords: antioxidant status, chocolate, mare's milk, resveratrol, vitamin E, toxic intoxication.

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Қорғасын ацетатымен уланған кезде мамандандырылған шоколад тұтынған егеуқұйрықтардың антиоксиданттық күйін зерттеу

Мақалада бие сүті негізінде дайындалған, ресвератрол мен Е дәрумені қосылған мамандандырылған шоколадты тұтынған жануарлардың антиоксиданттық күйін бағалауға бағытталған эксперименттік зерттеу нәтижелері баяндалады. Зерттеу барысында егеуқұйрықтарға 30 күн бойы асқазан ішіне қорғасын ацетаты енгізілгеннен кейін, олардың қан сарысуында липидтердің асқын тотығу процестерінің күшеюі байқалды. Бұл өзгерістер липидтердің асқын тотығу өнімдері – малонды диальдегид пен диенді конъюгаттардың деңгейінің артуымен сипатталды. Сонымен қатар, қан сарысуында Е дәруменінің және жалпы антиоксиданттық белсенділіктің төмендеуі тіркелді.

Липидтердің пероксидті тотығуының күшеюі каталаза белсенділігінің артуымен және супероксиддисмутаза белсенділігінің төмендеуімен қатар жүрді. Көрсеткіштердегі өзгерістердің барлығы статистикалық тұрғыда маңызы бар нәтижелер ретінде анықталды. Антиоксиданттық күйдің нашарлауы жануарлар рационын антиоксиданттық қасиеті жоғары өнімдермен немесе заттармен байытудың қажеттілігін көрсетті.

Зерттеу барысында қорғасын ацетатымен уланған егеуқұйрықтардың антиоксиданттық күйіне бие сүтімен, ресвератролмен және Е дәруменімен байытылған мамандандырылған

тың әсері бағаланды. Эксперименттің 30-күндік кезеңі аяқталғаннан кейін жануарларға тәулігіне 5 грамм шоколад берілген жағдайда, олардың антиоксиданттық күйінің жақсарғаны анықталды. Бұл қан сарысуында асқын тотығу өнімдерінің төмендеуімен, супероксиддисмутаза белсенділігінің жоғарылауымен, каталаза белсенділігінің қалыпқа келуімен, сондай-ақ Е дәрумені мен жалпы антиоксиданттық белсенділік деңгейінің артуымен көрініс тапты.

Алынған нәтижелер шоколадтың липидтердің асқын тотығу процестері мен антиоксиданттық жүйенің қызметіне оң әсер ететінін көрсетеді. Сонымен қатар, зерттеу нәтижелері мамандандырылған шоколадты қорғасын тұздарымен уланудың алдын алу шараларының бірі ретінде қолданудың тиімділігі мен мақсатқа сәйкестігін дәлелдейді.

Түйін сөздер: антиоксиданттық күй, шоколад, бие сүті, ресвератрол, Е дәрумені, токсикалық улану.

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Оценка антиоксидантного статуса крыс на фоне потребления специализированного шоколада при затравке ацетатом свинца

В статье излагаются данные экспериментальных исследований, касающиеся оценки антиоксидантного статуса животных при приеме специализированного шоколада, разработанного на основе кобыльего молока с добавлением ресвератрола и витамина Е. Показано, что после 30 дневной затравки крыс ацетатом свинца внутрижелудочно, в сыворотки крови крыс отмечалась активация процессов перекисного окисления липидов, сопровождающаяся накоплением как первичных, так и вторичных продуктов – малонового диальдегида и диеновых конъюгатов, снижением в крови содержания витамина Е и общей антиоксидантной активности.

Избыточное накопление перекисных соединений сопровождалось активацией каталазы и снижением активности супероксиддисмутазы. Следует отметить, что все полученные изменения в вышеуказанных показателях носили достоверный характер.

Снижение антиоксидантного статуса обосновывало целесообразность обогащения рациона животных в условиях свинцовой интоксикации продуктами с повышенным уровнем антиоксидантов и веществ антиоксидантной природы.

В представленном исследовании дана оценка специализированного шоколада, обогащенного кобыльим молоком, ресвератролом и витамином Е на состояние антиоксидантного статуса животных, подверженных токсической затравке ацетатом свинца. Установлено, что через 30 дней экспериментального периода потребление крысами по 5г специализированного шоколада в сутки способствовало повышению антиоксидантного статуса, что сопровождалось снижением в сыворотке крови животных продуктов ПОЛ, повышением активности супероксиддисмутазы, снижением активности каталазы и увеличением в сыворотке крови уровня витамина Е и общей антиоксидантной активности.

Полученные результаты свидетельствуют о благоприятном влиянии шоколада на состояние процессов ПОЛ-АОЗ, а также обосновывают целесообразность его использования с профилактической целью при отравлении организма солями свинца.

Ключевые слова: антиоксидантный статус, шоколад, кобылье молоко, ресвератрол, витамин Е, токсическая затравка.

Introduction

In recent years, significant changes have been observed in the structure of population morbidity, largely influenced by the impact of adverse environmental and etiological factors on the human body. Specifically, industrial production, metal extraction and processing, automobile emissions, and other factors contribute to an increase in various toxic substances and foreign compounds in the environ-

ment, among which heavy metal salts—particularly lead—hold a notable place [1,2].

Prolonged chronic exposure to lead at concentrations exceeding permissible limits often leads to the development of lead intoxication. Clinically, this condition primarily affects the hematopoietic, nervous, cardiovascular, immune, digestive, and hepatobiliary systems [3].

Various methods of treating and preventing lead intoxication exist; however, they unfortunately re-

quire prolonged use of medications, which are often not fully effective and are accompanied by numerous side effects [4].

Among the most promising preventive measures that do not lead to negative consequences are specialized products, biologically active supplements, and dietary additives. This experimental study focuses on alimentary prevention of lead intoxication using a specialized chocolate developed from mare's milk, enriched with vitamin E and resveratrol. Particular attention is given to supporting antioxidant status and regulating the antioxidant defense system through this novel dietary product, which possesses high biological value and targeted medical-biological properties.

Exposure to heavy metals, recognized as global environmental pollutants, is a leading factor in the development of numerous human diseases. The World Health Organization (WHO) has included lead on its list of priority pollutants [5]. Many illnesses that were previously diagnosed solely as occupational hazards are now being observed across the general population [3]. Powerful sources of environmental pollution by harmful substances, including metals and their salts, are non-ferrous metallurgy enterprises and their industrial waste [6].

The negative health impact extends from workers directly handling foreign compounds in industrial processes to the broader population. This occurs through environmental contamination and consumer goods containing lead, such as tiles, ceramics, crystal, and paints [7]. According to WHO, airborne lead particles alone cause approximately 7 million premature deaths annually. The overall contribution of air pollution to the global burden of disease is estimated by WHO experts to be 3.2% [5].

Lead is one of the most prevalent environmental pollutants and can enter the human body through water, food, air, and dust [8]. The harmful effects of lead are associated with its ability to impair the functions of multiple organs and systems, leading to damage in the kidneys, blood, liver, and respiratory system [9].

The development of methods to eliminate this toxicant from the body, as well as treatment protocols and therapeutic agents for lead poisoning, requires testing on biological models [10]. Given the wide-ranging negative effects of lead on the body, it is reasonable to focus on creating effective multifunctional preventive measures that can positively influence various metabolic processes. Particular attention should be paid to lead's role in exacerbating oxidative stress, impairing cardiovascular

function, increasing the risk of hypertension and atherosclerosis, and disrupting lipid metabolism in general [11].

Currently, there are no highly effective methods for preventing lead intoxication. Consequently, many researchers are investigating both pharmacological agents and dietary approaches to reduce the toxic burden of lead on the human body [12].

For the Republic of Kazakhstan, where not only lead extraction but also processing plants are present, this issue is particularly relevant. Workers in these industries mainly rely on milk and pectin-based preparations as preventive measures, which are not always effective in cases of lead intoxication.

In our study, we examined the role of specialized chocolate made from mare's milk, enriched with resveratrol and vitamin E, on the antioxidant defense system of animals subjected to toxic exposure to lead acetate.

Materials and methods

The research was conducted in the laboratory of food biotechnology and specialized food products at Kazakh Academy of Nutrition LLP. The study utilized sexually mature male rats weighing 180–200 grams, kept under vivarium conditions. The animals were housed in cages with free access to food and water. The vivarium-maintained air humidity at 50–65% and a temperature of 20–25°C. Before the experiment, the animals were quarantined for ten days.

A lead intoxication model was created by administering a 5% aqueous solution of lead acetate through a gastric tube. The daily dose was 1 ml per kilogram of body weight over a 30-day period.

The rats were divided into four groups, with 15 rats in each:

1. First group (Initial data) – Animals on a standard vivarium diet.
2. Second group – Animals received lead acetate exposure while on a standard vivarium diet.
3. Third group – Animals subjected to lead acetate exposure received a daily dose of 5 grams of specialized chocolate per 100 grams of body weight. This chocolate was developed from mare's milk (20%), cocoa butter, soy lecithin, sugar, and enriched with resveratrol (0.1%) and vitamin E (0.1%).
4. Control group – Animals under lead acetate exposure were given an equivalent-calorie glucose solution in addition to their regular diet. Animals weighing approximately 200 grams received an average of 10 grams of chocolate daily, providing 57.5 kcal. The control group animals were given

35–36 ml of a 40% glucose solution, matching the calorie content of the chocolate.

All animals were maintained on a basic vivarium diet balanced for essential nutrients for the 30-day duration of the experiment.

The specialized chocolate was administered after mild thermal processing (melting) and mixing with the food. The composition of the chocolate per 100 grams was as follows:

- Protein – 7.4 grams
- Fat – 33.84 grams
- Carbohydrates – 53.42 grams
- Caloric value – 575 kcal

Throughout the experimental period, the overall condition of the animals was monitored, and they were weighed every ten days.

The animal housing conditions and experimental procedures strictly adhered to the “European Convention for the Protection of Vertebrate Animals Used for Experimental and Scientific Purposes” and Directive 2010/63/EU of the European Parliament [13].

At the end of the 30-day period, the animals were euthanized under light ether anesthesia in accordance with the “Rules for Conducting Research with Experimental Animals” and the “Animal Protection Against Cruelty Act.”

The material used for the experimental study was rat blood serum.

In the serum, the vitamin E level was measured, and the condition of the antioxidant defense system was assessed. This included the determination of malondialdehyde (MDA), diene conjugates (DC), and the activity of catalase (CAT), superoxide dismutase (SOD), as well as total antioxidant activity (TAA).

The content of primary lipid peroxidation (LPO) products—diene conjugates (DC)—and secondary products—malondialdehyde (MDA)—was evaluated using the method of V.B. Gavrilov and M.I. Mishkorudna [14].

The activity of superoxide dismutase (SOD) and catalase (CAT) was measured spectrophotometrically using Sigma (Aldridge) kits and the method of M.A. Korolyuk, L.I. Ivanova, I.G. Mayorova, and V.E. Tokarev [15].

The total antioxidant activity (TAA) was assessed according to [16]. The concentration of vitamin E was determined in the hexane layer using high-performance liquid chromatography (HPLC) [17].

The obtained results were statistically processed using Microsoft Excel 2021. Arithmetic means, standard deviations, and standard errors were cal-

culated. Student’s t-test was applied to compare the data, and differences were considered significant at $p \leq 0.05$ [18].

Results and discussion

During lead acetate exposure, after ten days of observation, rats in the second and fourth (control) groups showed signs of coat deterioration, changes in the sclera of the eyes, and reduced motor activity. It is noteworthy that body weight in these groups decreased by an average of 20% by the 30th day of observation compared to baseline.

Consumption of chocolate during lead acetate exposure resulted in a 5% increase in body weight from the baseline within ten days of observation. Additionally, the overall condition of the animals improved, as reflected by better coat quality, normalized sclera appearance, and increased mobility. These positive changes were consistently observed throughout the 30-day experiment until the endpoint.

These improvements are likely due to the beneficial effects of the chocolate enriched with resveratrol and vitamin E on the endurance and protective functions of the rats’ bodies.

Of particular interest was the assessment of the lipid peroxidation-antioxidant defense (LPO-AOD) system under lead acetate exposure, including changes in the content of primary and secondary lipid peroxidation products and the state of the enzymatic antioxidant system.

It is known that lead intoxication often leads to oxidative stress and the accumulation of lipid peroxidation products in the body. This triggers a cascade of reactions that contribute to the onset and progression of hypertension and cardiovascular diseases [19,20].

According to the aforementioned authors, increased lipid peroxidation is accompanied by a range of negative consequences. These include a heightened risk of atherosclerosis, increased erythrocyte hemolysis, reduced membrane fluidity, and impaired erythroblast maturation, all of which occur against the backdrop of weakened protective mechanisms. These mechanisms play an active role in safeguarding membrane proteins and lipids from the damaging effects of peroxides and free radicals.

Lipid peroxidation can be considered a physiological process. However, the initiation and stability of cellular membrane resistance to oxidation largely depend on the body’s supply of antioxidants and antioxidant-based compounds. This is a crucial factor when evaluating the preventive effectiveness

of various pharmacological and dietary agents. In our opinion, this principle should serve as the foundation for developing new dietary-based preventive solutions [21,22]. This approach, in particular, guided the creation of a new specialized chocolate containing cocoa butter, cocoa mass, mare's milk, and supplemented with vitamin E and resveratrol.

Given the antioxidant focus in the selection of ingredients for the specialized chocolate, we evaluated its antioxidant properties using a rat model of lead acetate-induced toxicity.

The results regarding the antioxidant defense system under lead acetate exposure, based on rat blood serum analysis, are presented in Table 1.

Table 1 – Evaluation of Antioxidant Defense Parameters in Rat

Blood Serum under Lead Acetate-Induced Toxicity (M±m)

Groups	MDA (nmol/mL)	DC (nmol/mL)	Catalase (mmol/mg protein/min)	SOD (mmol/mg protein/min)
Group 1 (Initial data)	12,7±1,3	10,0±0,9	20,3±1,6	32,1±2,3
Group 2 (Lead acetate)	28,9±1,9*	15,6±1,2*	30,5±2,6*	22,6±1,2
Group 3 (Lead + Chocolate)	16,8±1,4**	12,4±0,9**	7,1±1,5	30,9±2,3**
Control Group	22,7±1,6**	16,1±0,8	26,5±2,2	23,6±1,9**

MDA: Malondialdehyde

DC: Diene Conjugates

SOD: Superoxide Dismutase

*Differences are statistically significant between the baseline (first) and lead acetate (second) groups ($p \leq 0.05$).

**Differences are statistically significant between the chocolate (third) group and both the lead acetate (second) and control (fourth) groups ($p \leq 0.05$).

As shown by the presented data, lead acetate exposure led to a significant increase in the levels of primary and secondary lipid peroxidation (LPO) products (MDA and DC) in the blood serum of rats after 30 days, compared to baseline values.

The accumulation of lead in rat tissues, accompanied by the activation of LPO processes, stimulated the formation of superoxide anions. This, in turn, resulted in a statistically significant 50.5% increase in catalase activity in the serum. Meanwhile, superoxide dismutase (SOD) activity

decreased significantly by 29.6% by the 30th day of the experiment. The increased levels of primary and secondary LPO products, along with changes in the activity of key antioxidant enzymes, indicated a reduction in endogenous antioxidant levels and justified the need for additional antioxidant intake.

This assumption was confirmed by the results on vitamin E concentration and total antioxidant activity (TAA) in rat blood serum under lead acetate exposure, as shown in Table 2.

Table 2 – Vitamin E Content and Total Antioxidant Activity in Rat Blood Serum During Lead Exposure and Specialized Chocolate Consumption

Groups	Vitamin E (µg/100 mL)	TAA (%)
Group 1 (Initial data)	0,72±0,03	65,3±3,6
Group 2 (Lead acetate)	0,45±0,03*	40,5±3,8*
Group 3 (Lead + Chocolate)	0,65±0,04**	59,3±4,9**
Control Group	0,40±0,02**	42,3±4,9

*Differences are statistically significant between the baseline (first) and lead acetate (second) groups ($p \leq 0.05$).

**Differences are statistically significant between the chocolate (third) group and both the lead acetate (second) and control (fourth) groups ($p \leq 0.05$).

As shown in Table 2, in the lead acetate exposure group (second group), a significant decrease in vitamin E content by 37.5% was observed by the 30th day of the experiment compared to the baseline group (first group). Additionally, total antioxidant activity (TAA) decreased by 24.8%. These changes indicate depletion of endogenous antioxidant reserves in the rats due to toxic exposure and increased utilization of antioxidants to normalize lipid peroxidation (LPO) processes, reduce toxic stress, and maintain overall metabolic balance.

The activation of LPO and the decline in antioxidant status in rats exposed to lead acetate justified the use of products enriched with natural antioxidants as a preventive measure. Such products can reduce the risk of initiating lipid peroxidation and the activation of the LPO-antioxidant defense (LPO-AOD) system as a whole.

Given these findings, we evaluated the effects of specialized chocolate, which was administered to the rats with their diet over 30 days under lead acetate exposure.

As shown by the data in Table 1, in the third group (lead + chocolate), there was a statistically significant reduction in primary and secondary LPO products in the blood serum on the 30th day of the experiment compared to the second (lead acetate) and fourth (lead + glucose) groups.

For example, the level of malondialdehyde (MDA) in the third group decreased by 41.9% compared to the second group and by 30.0% compared to the fourth group. Similarly, the content of primary LPO products (diene conjugates) in the blood serum decreased by 20.5% and 29.8% compared to the second and fourth groups, respectively, with these differences being statistically significant.

The increased antioxidant supply in the rats, particularly vitamin E, was confirmed by the serum vitamin E data in the third group. As shown in Table 2, the vitamin E content in the third group increased by an average of 33.3% compared to the second and fourth groups. Additionally, the reduction in vitamin E levels in the third group under lead acetate exposure was 3.4 times smaller than the decline observed from the baseline.

Furthermore, total antioxidant activity in the third group was higher by 18.8% and 17.0% com-

pared to the second and fourth groups, respectively. These findings demonstrate the positive effect of specialized chocolate enriched with vitamin E and resveratrol on mitigating oxidative stress and improving antioxidant status in rats under lead acetate toxicity.

The results of antioxidant activity between the second and third groups were statistically significant.

Thus, the conducted research demonstrated the positive effects of specialized chocolate, developed from mare's milk and enriched with resveratrol and vitamin E, on the lipid peroxidation-antioxidant defense (LPO-AOD) system in animals subjected to lead acetate toxicity. The chocolate positively influenced the overall physiological condition of the rats, including the condition of their coat, feed consumption, and body weight changes. The additional intake of vitamin E and resveratrol through the chocolate improved not only the antioxidant supply but also the activity of key antioxidant enzymes and reduced the levels of primary and secondary LPO products in the rats' blood serum.

Conclusion

The purpose of the study was to evaluate the effectiveness of specialized chocolate during a 30-day lead acetate exposure in rats. Using a well-founded methodological approach, the study confirmed with a high degree of reliability the benefits of dietary support through the developed product.

The experimental findings on the properties of specialized chocolate, made with powdered mare's milk, vitamin E, and resveratrol, provided statistically significant evidence supporting the use of dietary intervention in cases of lead poisoning. Special attention should be given to inhibiting lipid peroxidation processes, one of the key mechanisms responsible for structural and functional damage to biological and membrane integrity under toxic lead exposure.

Based on the obtained experimental data, it is recommended to use the specialized chocolate as a preventive measure for individuals exposed to heavy metals, particularly lead, which enters the body through various pathways.

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Received February 10, 2024

Accepted May 20, 2025