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STRENGTH FEATURES OF THE LOWER INCISOR/MANDIBULAR COMPLEX IN WHITE RATS AFTER 60-DAY TARTRAZINE ADMINISTRATION AND TIBIAE DEFECTS

Research article

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Abstract

The aim of this study was to analyze the strength features of the lower incisor/mandibular complex in white rats after 60-day tartrazine administration and tibiae defects.

Material and methods. The study included 240 female rats with initial body weight 200-210 g. All animals were divided into several groups: group 1st (KBC) – control animals; group 2nd (TTZ1500) consisted of rats that were intragastrically administered 1 ml of tartrazine at a dose of 1500 mg/kg/day; group 3rd (DBK) – comprised animals with round opening in the proximal metaphysis of both tibiae made upon expiration of 60-day intake of tartrazine. The TTZ1500D group consisted of rats that had a tibial defect after 60 days of tartrazine administration, and the TTZ1500DM, TTZ1500DT, TTZ1500M, and TTZ1500T groups included rats with or without tibial damage that were simultaneously injected intraperitoneally with tartrazine inoculation and given mexidol at a dose of 50 mg/kg/day or thiotriazoline at a dose of 117,4 mg/kg/day.

Results. After tartrazine administration, the strength features of the lower incisor/mandibular complex were impaired. The changes were maximum on the 3rd day after thiotriazoline administration, and by the 45th day, reliable differences from the control group still remained. Tibiae defects led to an aggravation of the strength impairment and a slowdown in its recovery. The administration of mexidol at a dose of 50 mg/kg/day or thiotriazoline at a dose of 117,4 mg/kg/day simultaneously with tartrazine smoothed out the disturbances in the strength of the lower incisor/mandibular complex. The use of thiotriazoline was more effective.

Keywords: rats, strength features, fracture, tartrazine, tibia, incisor/mandibular complex.

ПРОЧНОСТНЫЕ ХАРАКТЕРИСТИКИ КОМПЛЕКСА НИЖНЯЯ ЧЕЛЮСТЬ/РЕЗЕЦ У БЕЛЫХ КРЫС С ДЕФЕКТОМ БОЛЬШЕБЕРЦОВОЙ КОСТИ ПОСЛЕ 60-ДНЕВНОГО ПРИМЕНЕНИЯ ТАРТРАЗИНА

Научная статья

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Аннотация

Целью данного исследования было изучение прочностных характеристик комплекса нижняя челюсть/резец у белых крыс после 60-дневного введения тартразина и дефектов большеберцовых костей.

Материал и методы. Исследование было проведено на 240 самках крыс с исходной массой тела 200-210 г. Все животные были разделены на несколько групп: 1-я группа (КБК) – контрольные животные; 2-я группа (ТТ31500) – крысы, которым внутрижелудочно вводили 1 мл тартразина в дозе 1500 мг/кг/сут; 3-я группа (ДБК) – животные, которым по истечении 60-дневного приема тартразина производили круглое отверстие в проксимальном метафизе обеих большеберцовых костей. Группа ТТ31500Д животных, которым по истечении 60 дней после введения тартразина наносили дефект большеберцовой кости, а группы ТТ31500ДМ, ТТ31500ДТ, ТТ31500М и ТТ31500Т – крысы с повреждением большеберцовой кости или без него, которым одновременно внутрибрюшинно вводили тартразин и мексидол в дозе 50 мг/кг/сут или тиотриазолин в дозе 117,4 мг/кг/сут.

Результаты. После введения тартразина нарушались прочностные показатели комплекса нижняя челюсть/резец. Максимальные изменения наблюдались на 3-е сутки после введения тиотриазолина, к 45-му дню достоверные отличия от контрольной группы сохранялись. Дефекты большеберцовых костей приводили к ухудшению прочностных характеристик и замедлению их восстановления. Назначение мексидола в дозе 50 мг/кг/сут или тиотриазолина в дозе 117,4 мг/кг/сут одновременно с тартразином нивелировало нарушения прочностных характеристик комплекса нижняя челюсть/резец. Применение тиотриазолина было более эффективным.

Ключевые слова: крысы, прочностные характеристики, тартразин, большеберцовая кость, комплекс нижняя челюсть/резец.

Introduction

Tartrazine is one of the most common food colorings, which is widely used in the food, leather, cosmetic and textile industries, as well as in drug capsules such as antacids and vitamins, especially in many developing countries. Tartrazine is absorbed by the intestinal epithelium and metabolized by microflora and possibly by azoreductase in the liver or intestinal wall of mammals to sulfanilic acid, which has potential carcinogenic properties [1]. Oral administration of tartrazine results in the excretion of equal amounts of partially conjugated sulfanilic acid in rats, rabbits and humans. Tartrazine has been shown to cause various behavioral changes such as hyperactivity, irritability, restlessness and sleep disturbances in children. In addition, the widespread use of tartrazine has led to various disorders, such as thyroid cancer, asthma, eczema, migraine, genotoxicity, liver and kidney damage, and infertility [2]. There is also evidence that excessive use of tartrazine can disrupt hormonal balance, growth, and development of the body [3]. All of the above factors have a negative impact on the state of the skeletal system and are risk factors for the development of low-energy fractures [4]. In order to ensure the process of osteoreparation, the body as a whole, responds to damage to even one of the bones with a complex of reactions from almost all organs and systems [5]. Morphological reactions in response to a fracture and from the dental system have been studied in sufficient detail [6]. However, there is no information in the available literature about the morphological reaction of the dental system after fracture of the skeletal bones in biological objects that have consumed high doses of tartrazine for a long period of time.

Material and methods

The study included 240 female rats with initial body weight 200-210 g. All animals were divided into several groups: group 1st (KBC) – control animals; group 2nd (TTZ1500) consisted of rats that were intragastrically administered 1 ml of tartrazine at a dose of 1500 mg/kg/day; group 3rd (DBK) – comprised animals with round opening in the proximal metaphysis of both tibiae made upon expiration of 60-day intake of tartrazine. The TTZ1500D group consisted of rats that had a tibial defect after 60 days of tartrazine administration, and the TTZ1500DM, TTZ1500DT, TTZ1500M, and TTZ1500T groups included rats with or without tibial damage that were simultaneously injected intraperitoneally with tartrazine inoculation and given mexidol at a dose of 50 mg/kg/day or thiotriazoline at a dose of 117,4 mg/kg/day [7], [8]. The observation terms were 3, 10, 15, 24, and 45 days, which corresponds to the stages of bone regenerate formation [9]. At the end of the observation terms, the rats were euthanized under anesthesia, and the lower incisor/mandibular complex was isolated. Biomechanical testing of lower incisor/mandible complex was performed by means of three-point bending technique with loading speed of 10 μm per minute. Strength values (minimum fracture energy, destruction moment, specific sag, elasticity modulus, and ultimate strength) were calculated from dislocation curves [10]. The statistical significance of differences between age-matched groups of experimental animals was assessed using the Statistica 10.0 program, Statsoft, USA, using the Student's T-test; differences were considered statistically significant at $p \leq 0,05$ [11].

Results and discussion

In the animals of the KBC group, for the lower incisor/mandibular complex, from the 1st to the 60th day of observation terms, the specific sag decreased from 6,32±0,09 N/μM to 6,05±0,10 N/μM, which reflects an increase in its rigidity. Other indicators of the ultimate strength of the lower incisor/mandibular complex increased during the observation: the destruction moment – from 117,45±1,64 N/μM to 128,27±1,85 N/μM, and the minimum fracture energy – from 77,85±0,94 μJ to 86,26±1,47 μJ. The elasticity modulus of the lower incisor/mandibular complex decreased from 21,34±0,26 GPa to 19,31±0,30 GPa, and the ultimate strength decreased from 471,70±7,10 to 431,63±6,27 GPa (Table 1).

Table 1 - Dynamics of the strength features of the lower incisor/mandibular complex in pre-senile and senile rats without damage to the tibia

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Group	Terms	Specific sag, N/μM	Destruction moment, N/mM	Ultimate strength, GPa	Elasticity modulus, GPa	Fracture energy, mJ
KBC	3	6,32±0,09	117,45±1,64	471,70±7,10	21,34±0,26	77,85±0,94
	10	6,28±0,10	119,02±1,66	463,91±6,84	20,11±0,33	78,26±1,10
	15	6,21±0,10	121,22±1,76	458,30±5,42	20,01±0,30	80,30±1,14
	24	6,18±0,10	123,15±1,75	445,69±5,80	19,98±0,30	82,46±1,61
	45	6,05±0,09	128,27±1,85	431,63±6,27	19,31±0,30	86,26±1,47
TTZ 1500	3	5,78±0,09*	102,24±1,27*	419,33±6,19*	22,39±0,36*	67,73±0,95*
	10	5,73±0,11*	105,15±1,11*	409,99±4,80*	21,51±0,31*	69,94±1,04*
	15	5,85±0,09*	110,77±1,64*	416,65±6,54*	20,09±0,33	72,00±1,02*
	24	5,90±0,11	116,25±1,50*	414,23±3,94*	19,04±0,28*	76,45±1,10*
	45	5,94±0,09	120,05±1,66*	403,72±6,18*	18,94±0,32	80,68±1,46*
TTZ	3	5,95±0,07*	104,81±1,49	431,95±6,47	22,28±0,31*	70,28±1,06*

Group	Terms	Specific sag, N/μM	Destruction moment, N/mM	Ultimate strength, GPa	Elasticity modulus, GPa	Fracture energy, mJ
1500M			*	*		
	10	5,93±0,09*	107,94±1,48*	435,38±5,95*^	21,39±0,28*	72,94±1,20*
	15	6,00±0,11	113,10±1,66*	441,22±6,91^	20,02±0,29	75,14±1,05
	24	5,99±0,09	117,89±1,51*	431,57±6,30^	19,90±0,30	79,31±1,50
	45	5,95±0,11	125,38±1,78^	421,24±5,74	18,96±0,24	83,90±1,35
TTZ1500T	3	5,98±0,08*	105,71±1,47*	436,58±6,16*	22,07±0,31	72,07±0,92*^
	10	5,99±0,11	107,92±1,60*	442,34±5,72*^	21,06±0,28*	74,00±0,97*^
	15	6,02±0,10	114,11±1,57*	447,24±6,80^	19,76±0,27	76,14±1,01*^
	24	6,10±0,11	118,36±1,57	436,20±6,79^	19,68±0,29	80,13±0,92^
	45	5,97±0,10	126,13±1,52^	426,45±6,85^	19,06±0,29	85,12±0,98^

Note: (X±Sx).
** – indicates a statistically significant difference from the KBC group (p≤0,05);*
^ – indicates a statistically significant difference from the TTZ1500 group (p≤0,05)

Intragastric administration of tartrazine 1500 mg/kg/day to experimental animals for 60 days was accompanied by a decrease in the strength of the lower incisor/mandibular complex. From 3 to 45 day after the end of the challenge, the following values were lower than the values of the DBK group: the destruction moment of the lower incisor/mandibular complex – by 12,95%, 11,66%, 8,62%, 5,60% and 6,41%, the ultimate strength – by 11,10%, 11,62%, 9,09%, 7,06% and 6,47%, as well as the minimum destruction work – by 12,99%, 10,63%, 10,34%, 7,29% and 6,47% (all the numerical differences given here and below are statistically significant, p≤0,05). Also, from the 3rd to the 15th day of the readaptation period, the specific sag of the lower incisor/mandibular complex was lower than the values of the KBC group by 8,52%, 8,76% and 5,75%, and the elasticity modulus by the 3rd and 10th days was higher by 4,89% and 7,00%. This indicates an increase in the rigidity of the lower incisor/mandibular complex from the 3rd to the 15th day of the readaptation period. DBK group was also accompanied by a decrease in the strength characteristics of the lower incisor/mandibular complex. The destruction moment of the lower incisor/mandibular complex in animals of the DBC group from 10 to 45 days after the operation was lower than the values of the KBC group by 6,08%, 7,29%, 10,55% and 4,70%, and the value of the specific sag arrow exceeded them by 5,57%, 7,82%, 9,53% and 7,68%. At the same time, the ultimate strength and the minimum fracture energy of the lower incisor/mandibular complex from 15 to 45 days after the operation lagged behind the values of the KBC group by 5,12%, 8,43% and 6,18%, and by 5,33%, 9,38% and 6,10%, respectively, and the elasticity modulus by 24 and 45 days – by 8,49% and 5,01%. The defect in the tibia after 60-day tartrazine administration at a dose of 1500 mg/kg/day was accompanied by an aggravation of the strength impairment of the lower incisor/mandibular complex. At the same time, the strength impairment in the TTZ1500D group in comparison with the TTZ1500 group was usually maximal on the 24th day after the end of the administration, then gradually recovered, but by the 45th day of the readaptation period, a statistically significant difference in all studied parameters from the TTZ1500 group remained. In comparison with the parameters of the TTZ1500 group, the specific sag of the lower incisor/mandibular complex from the 3rd to the 45th day after the operation increased by 6,05%, 13,12%, 19,84%, 23,47% and 18,46% (Table 2). At the same time, the breaking moment and elasticity modulus were less than the values of the TTZ1500 group from the 10th to the 45th day after the operation by 5,32%, 9,88%, 13,95% and 5,26%, and by 15,42%, 10,64%, 9,42% and 6,81%, the ultimate strength from the 15th to the 45th day - by 5,98%, 10,19% and 5,96%, and the minimum fracture energy from the 24th to the 45th day – by 9,42% and 6,81%.

Table 2 - Dynamics of the strength of the lower incisor/mandibular complex in pre-senile white rats with damage to the tibia

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Group	Terms	Specific sag, N/μM	Destruction moment, N/mM	Ultimate strength, GPa	Elasticity modulus, GPa	Fracture energy, mJ
DBK	3	6,58±0,08	112,85±1,57	457,34±6,53	20,61±0,26	75,11±1,10

Group	Terms	Specific sag, N/μM	Destruction moment, N/mM	Ultimate strength, GPa	Elasticity modulus, GPa	Fracture energy, mJ
	10	6,63±0,10*	111,79±1,51 *	443,45±6,63	19,75±0,28	75,13±1,07
	15	6,70±0,09*	112,38±1,75 *	434,82±6,26 *	19,26±0,31	76,02±1,24*
	24	6,77±0,09*	110,15±1,75 *	408,10±5,53 *	18,29±0,28*	74,72±1,09*
	45	6,51±0,09*	122,24±1,65 *	404,97±7,28 *	18,35±0,29*	81,00±1,61*
TTZ 1500 D	3	6,13±0,09	100,03±1,53 ^	407,55±5,44 ^	19,16±0,29^	65,89±0,91^
	10	6,48±0,09	99,55±1,33^	400,86±5,47 ^	18,20±0,28^	67,99±0,94^
	15	7,02±0,10^	99,82±1,41^	391,73±5,43 ^	17,95±0,27^	69,23±1,02^
	24	7,29±0,13^	100,04±1,39 ^	372,02±4,78 ^	17,37±0,31^	69,25±1,02^
	45	7,04±0,09^	113,73±1,69 ^	379,67±4,97 ^	16,76±0,90	75,18±1,15^
TTZ 1500 DM	3	6,27±0,09^	103,72±1,44 ^	423,94±6,07 ^	19,14±0,50^	69,05±1,00^ #
	10	6,46±0,09	104,91±1,60 ^#	419,53±6,78	18,61±0,31^	71,31±0,94^ #
	15	6,99±0,09^	105,65±1,40 ^#	401,04±17,6 3	18,22±0,31^	72,00±0,91^
	24	7,08±0,10^	106,83±1,33 #	388,85±5,98 ^#	17,85±0,29	72,36±1,01#
	45	6,79±0,10	115,95±1,47 ^	393,98±5,82	17,79±0,27	76,89±1,06
TTZ 1500 DT	3	6,33±0,08	105,95±1,52 ^#	433,00±5,95 *#	19,59±0,25^	69,68±0,92^ #
	10	6,52±0,10	106,11±1,57 ^#	423,73±5,93 ^#	18,92±0,28	71,91±1,02^ #
	15	6,94±0,08	107,13±1,40 ^#	414,54±6,21 ^#	18,33±0,29^	72,89±0,97#
	24	7,04±0,09^	106,94±1,45 #	391,97±6,33 #	18,01±0,27	73,90±0,94#
	45	6,77±0,09	118,20±1,48	398,60±5,70 #	17,90±0,28	78,28±0,75#

Note: (X±Sx).
** – indicates a statistically significant difference from the KBC group (p≤0,05);*
^ – indicates a statistically significant difference from DBK group (p≤0,05);
 # – indicates a statistically significant difference from the similar group without using a corrector (p≤0,05)

Intraperitoneal administration of mexidol at a dose of 50 mg/kg/day or thiotriazoline at a dose of 117,4 mg/kg/day simultaneously with 60-day tartrazine administration both without damaging the tibia and after causing defects in them was accompanied by a tendency to restoration the strength of the lower incisor/mandibular complex. In the TTZ1500M group, when compared with the TTZ1500 group, statistically significant differences in the strength characteristics of the lower incisor/ mandibular complex were recorded from days 10 to 45 of the readaptation period. The ultimate strength of the lower incisor/mandibular complex in animals of the TTZ1500T group exceeded the comparison values from 10 to 45 days by 6,19%, 5,89%, 4,19% and 4,34%, and the breaking moment by day 45 by 4,44%. When comparing the results of biomechanical tests of the lower incisor/mandibular complex in animals of the TTZ1500T group with the TTZ1500 group, statistically significant differences were recorded from day 3 to day 45 of the readaptation period. The minimum fracture energy of the lower incisor/mandibular complex was greater than the values of the TTZ1500 group from the 3rd to the 45th day of the readaptation period by 6,40%, 5,80%, 5,76%, 4,82% and 5,51%, the ultimate strength from the 10th to the 45th day – by 7,89%, 7,34%, 5,30% and 5,63%, and the breaking moment by the 45th day – by 5,06%. In the TTZ1500DM group, when compared with the

TTZ1500D group, statistically significant differences in the studied indicators were observed from the 3rd to the 24th day of the readaptation period. In this case, the minimum fracture energy of the lower incisor/mandibular complex in animals of the TTZ1500DM group was greater than the values of the TTZ1500D group by 3, 10 and 24 days of the readaptation period by 4,80%, 4,89% and 4,50%, the breaking moment from 10 to 24 days – by 5,38%, 5,84% and 6,79%, and the ultimate strength by 24 days – by 4,52%.

Finally, in animals of the TTZ1500DT group, the ultimate strength and the minimum fracture energy of the lower incisor/mandibular complex from the 3rd to the 45th day of the readaptation period exceeded the values of the TTZ1500D group by 6,24%, 5,71%, 5,82%, 5,365 and 4,99%, and by 5,76%, 5,77%, 5,29%, 6,72% and 4,12%, respectively. Also, the breaking moment of the lower incisor/mandibular complex from the 3rd to the 24th day exceeded the values of the TTZ1500D group by 5,92%, 6,59%, 7,32% and 6,90%. Thus, intragastric administration of tartrazine to mature rats at a dose of 1500 mg/kg/day for 60 days is accompanied by a violation of the strength of the lower incisor/mandibular complex, most pronounced immediately after the end of the administration. The violations of strength were maximal on the 3rd day after the end of the administration, then gradually recovered, but by the 45th day of the readaptation period, a statistically significant difference in the studied parameters from the KBC group remained. It is known that tartrazine causes direct damage to the mitochondrial DNA molecule, which leads to the development of oxidative stress, to a violation of ATP synthesis in the body's cells [12] and, probably, in the odontoblasts of the lower incisor, osteoblasts of the periosteum and chondroblasts of the condylar cartilages of the mandible. Tartrazine also acts as a chelating agent with copper, zinc and manganese molecules in the small intestine [13], and therefore binds them. These trace elements act as cofactors of various enzymes and energy cycles, as a result of which their deficiency can also negatively affect the morpho-functional activity of the odontoblasts of the lower incisor, osteoblasts of the periosteum and chondroblasts of the condylar cartilages of the mandible. As a result, this is accompanied by a violation of the strength characteristics of the lower incisor/mandibular complex. However, as follows from the results obtained, after the cessation of tartrazine exposure, the strength of the lower incisor/mandibular complex tends to recover. Also, damage to one of the bones is accompanied by a complex of reactions aimed at ensuring the processes of reparative bone regeneration and mobilization of calcium and phosphorus from all mineralized tissues of the body [5]. Therefore, the application of a defect to the tibia after 60 days of tartrazine administration is accompanied by an aggravation of the inhibition of growth processes in the lower incisors. Administration of mexidol has a corrective effect on the strength characteristics of the lower incisor/mandibular complex, which can be explained by its membrane-protective, antioxidant and antihypoxic properties [14], [15]. At the same time, similar properties of thiotriazoline are more pronounced [16], which determines its more pronounced corrective effect on the studied parameters.

Conclusion

Excessive use of tartrazine in experimental animals at a dose of 1500 mg/kg/day for 60 days is accompanied by a decrease in the strength of the lower incisor/mandibular complex. Strength impairments were maximal on the 3rd day after the end of the administraion, then gradually recovered, but by the 45th day of the readaptation period, a statistically significant difference in the studied parameters from the control group remained. Surgical perforation of the tibia at the end of tartrazine administration leads to an aggravation of the strength impairment of the lower incisor/mandibular complex and a slowdown in its recovery during the readaptation period. Simultaneous use of mexidol or thiotriazoline with tartrazine smooths out the strength impairments of the lower incisor/mandibular complex. The use of thiotriazoline is more effective.

Конфликт интересов

Не указан.

Рецензия

Все статьи проходят рецензирование. Но рецензент или автор статьи предпочли не публиковать рецензию к этой статье в открытом доступе. Рецензия может быть предоставлена компетентным органам по запросу.

Conflict of Interest

None declared.

Review

All articles are peer-reviewed. But the reviewer or the author of the article chose not to publish a review of this article in the public domain. The review can be provided to the competent authorities upon request.

Список литературы / References

1. Erdemli Z. Ameliorative effects of crocin on tartrazine dye-induced pancreatic adverse effects: a biochemical and histological study / Z. Erdemli, E. Altinoz, M.E. Erdemli [et al.] // Environmental Science and Pollution Research. — 2021. — Vol. 28. — № 2. — P. 2209–2218. — DOI: 10.1007/s11356-020-10578-6. — EDN ANBEHR.

2. Kamal A.A. Toxicological and safety assessment of tartrazine as a synthetic food additive on health biomarkers: a review / A.A. Kamal, S.A.-S. Fawzia // African Journal of Biotechnology. — 2018. — Vol. 17. — № 6. — P. 139–149. — DOI: 10.5897/AJB2017.16300.

3. Raposa B. Food additives: Sodium benzoate, potassium sorbate, azorubine, and tartrazine modify the expression of NFκB, GADD45α, and MAPK8 genes / B. Raposa, R. Pónusz, G. Gerencsér [et al.] // Physiology International. — 2016. — Vol. 103. — № 3. — P. 334–343. — DOI: 10.1556/2060.103.2016.3.6.

4. Ковешников В.Г. Экологическая морфология органов эндокринной, иммунной и костной систем в условиях хронического ингаляционного влияния летучих компонентов эпоксидных смол / В.Г. Ковешников, К.А. Фомина, В.В. Фоменко [и др.] // Астраханский медицинский журнал. — 2013. — Т. 8. — № 1. — С. 128–130. — EDN QCYCXR.

5. Лузин В.И. Прочность плечевой кости при имплантации в большеберцовую кость гидроксиапатитного материала ОК-015 [Электронный ресурс] / В.И. Лузин, В.К. Ивченко, Д.В. Ивченко [и др.] // Травма. — 2007. — Т. 8. — № 4. — 387 с.

6. Лузин В.И. Макро- и микроэлементный состав нижней челюсти половозрелых крыс при имплантации в большеберцовую кость биогенного гидроксилапатита, насыщенного солями железа в различных концентрациях / В.И. Лузин, В.Н. Морозов // Вестник проблем экологии и медицины. — 2012. — Т. 1. — № 3 (94). — С. 145–149.

7. Лузин В.И. Динамика темпов роста костей у белых крыс после ингаляционной обработки толуолом и возможные пути ее коррекции / В.И. Лузин, Е.Ю. Шутов, А.Н. Скоробогатов // Украинский медицинский журнал. Морфологический альманах. — 2011. — Т. 9. — № 2. — С. 47–50. — EDN RPAEKX.

8. Bibik V.V. Influence of Tartrazine on histological structure of the mandibular condylar cartilage / V.V. Bibik, V.I. Luzin, N.A. Mosyagina [et al.] // Aging-Clinical and Experimental Research. — 2024. — Vol. 36. — № S1. — DOI: 10.1007/s40520-024-02766-y.

9. Корж Н.А. Репаративная регенерация кости: современный взгляд на проблему. Стадии регенерации / Н.А. Корж, Н.В. Дедух // Ортопедия, травматология и протезирование. — 2006. — Т. 1. — С. 77–84.

10. Mosyagina N.A. Strength features of the tibia in diabetic rats after repeated fracture / N.A. Mosyagina, D.A. Astrakhantsev // Bone Reports. — 2022. — Vol. 16. — 101347 p. — DOI: 10.1016/j.bonr.2022.101347. – EDN ODMUMK.

11. Mosyagina N.A. Bone matrix dependent strength features of the tibia in diabetic rats with repeated fracture after systemic and local calcium administration / N.A. Mosyagina // JBMR Plus. — 2024. — Vol. 8. — № S1. — i109 p. — DOI: 10.1093/jbmrpl/ziae063. — EDN OXPDSD.

12. Лукьянцева Г.В. Влияние 60-дневного введения бензоата натрия на прочностные характеристики костей скелета белых крыс в период реадаптации / Г.В. Лукьянцева, В.И. Лузин, В.Н. Морозов // Травма. — 2014. — Т. 15. — № 3. — С. 30–32. — EDN SNMKAB.

13. Amin K.A. Toxicological and safety assessment of tartrazine as a synthetic food additive on health biomarkers: A review / K.A. Amin, F.S. Al-Shehri // African Journal of Biotechnology. — 2018. — Vol. 17. — № 6. — P. 139–149. — DOI: 10.5897/AJB2017.16300.

14. Visweswaran B. Oxidative Stress by Tartrazine in the Testis of Wistar Rats / B. Visweswaran, G. Krishnamoorthy // Journal of Pharmacy and Biological Sciences. — 2012. — Vol. 2. — № 3. — P. 44–49. — DOI: 10.9790/3008-0234447.

15. Воронина Т.А. Мексидол: основные нейропсихотропные эффекты и механизм действия / Т.А. Воронина // Фарматека. — 2009. — № 6 (180). — С. 28–31. — EDN KXDBCF.

16. Пороховская Н.В. Мембранозащитные и антиоксидантные свойства тиотриазолина в условиях острого иммунокомплексного процесса / Н.В. Пороховская, М.С. Регеда // Экспериментальная физиология и биохимия. — 2007. — Т. 3. — С. 35–39.

Список литературы на английском языке / References in English

1. Erdemli Z. Ameliorative effects of crocin on tartrazine dye-induced pancreatic adverse effects: a biochemical and histological study / Z. Erdemli, E. Altinoz, M.E. Erdemli [et al.] // Environmental Science and Pollution Research. — 2021. — Vol. 28. — № 2. — P. 2209–2218. — DOI: 10.1007/s11356-020-10578-6. — EDN ANBEHR.

2. Kamal A.A. Toxicological and safety assessment of tartrazine as a synthetic food additive on health biomarkers: a review / A.A. Kamal, S.A.-S. Fawzia // African Journal of Biotechnology. — 2018. — Vol. 17. — № 6. — P. 139–149. — DOI: 10.5897/AJB2017.16300.

3. Raposa B. Food additives: Sodium benzoate, potassium sorbate, azorubine, and tartrazine modify the expression of NFκB, GADD45α, and MAPK8 genes / B. Raposa, R. Pónusz, G. Gerencsér [et al.] // Physiology International. — 2016. — Vol. 103. — № 3. — P. 334–343. — DOI: 10.1556/2060.103.2016.3.6.

4. Koveshnikov V.G. Ekologicheskaya morfologiya organov endokrinnoi, immunnoi i kostnoi sistem v usloviyakh khronicheskogo ingalyatsionnogo vliyaniya letuchikh komponentov epoksidnykh smol [The ecological morphology of the organs of endocrine, immune and bone systems under the of chronic inhalation influence of volatile components of epoxy resins] / V.G. Koveshnikov, K.A. Fomina, V.I. Luzin [et al.] // Astrakhanskii meditsinskii zhurnal [Astrakhan Medical Journal]. — 2013. — Vol. 8. — № 1. — P. 128–130. — EDN QCYCXR. [in Russian]

5. Luzin V.I. Prochnost' plechevoi kosti pri implantatsii v bol'shebertsovuyu kost' gidroksiapatitnogo materiala OK-015 [Strength of the humerus after implantation of hydroxyapatite material OK-015 into the tibia] / V.I. Luzin, V.K. Ivchenko, D.V. Ivchenko [et al.] // Travma [Injury]. — 2007. — Vol. 8. — № 4. — 387 p. [in Russian]

6. Luzin V.I. Makro- i mikroelementnyi sostav nizhnei chelyusti polovozrelykh krys pri implantatsii v bol'shebertsovuyu kost' biogennogo gidroksiapatita, nasyshchennogo solyami zheleza v razlichnykh kontsentratsiyakh [Macro- and lower jaw trace element composition of adult rats under implantation in the tibia biogenic hydroxylapatite, saturated with iron salts in various concentrations] / V.I. Luzin, V.N. Morozov // Vestnik problem jekologii i mediciny [Bulletin of Problems of Ecology and Medicine]. — 2012. — Vol. 1. — № 3 (94). — P. 145–149. [in Russian]

7. Luzin V.I. Dinamika tempov rosta kostei u belykh krys posle ingalyatsionnoi zatravki toluolom i vozmozhnye puti ee korrektsii [The dynamics of growth of bones in white rats after inhalation poisoning with toluene and the possible ways of its correction] / V.I. Luzin, E.Yu. Shutov, A.N. Skorobogatov // Ukrainskij medicinskij zhurnal. Morfologicheskij al'manah [Ukrainian Medical Journal. Morphological almanac]. — 2011. — Vol. 9. — № 2. — P. 47–50. — EDN RPAEKX. [in Russian]

8. Bibik V.V. Influence of Tartrazine on histological structure of the mandibular condylar cartilage / V.V. Bibik, V.I. Luzin, N.A. Mosyagina [et al.] // Aging-Clinical and Experimental Research. — 2024. — Vol. 36. — № S1. — DOI: 10.1007/s40520-024-02766-y.

9. Korzh N.A. Reparativnaya regeneratsiya kosti: sovremennyi vzglyad na problemu. Stadii regeneratsii [Reparative bone regeneration: a modern view of the problem. Stages of regeneration] / N.A. Korzh, N.V. Dedukh // Ortopedija, travmatologija i protezirovanie [Orthopedics, Traumatology and Prosthetics]. — 2006. — Vol. 1. — P. 77–84. [in Russian]

10. Mosyagina N.A. Strength features of the tibia in diabetic rats after repeated fracture / N.A. Mosyagina, D.A. Astrakhantsev // Bone Reports. — 2022. — Vol. 16. — 101347 p. — DOI: 10.1016/j.bonr.2022.101347. – EDN ODMUMK.

11. Mosyagina N.A. Bone matrix dependent strength features of the tibia in diabetic rats with repeated fracture after systemic and local calcium administration / N.A. Mosyagina // JBMR Plus. — 2024. — Vol. 8. — № S1. — i109 p. — DOI: 10.1093/jbmrpl/ziae063. — EDN OXPDSD.

12. Lukyantseva G.V. Vliyanie 60-dnevnogo vvedeniya benzoata natriya na prochnostnye kharakteristiki kostei skeleta belykh krys v period readaptatsii [The effects of 60-day administration of sodium benzoate on strength features of skeletal bones in white rats in readaptation period] / G.V. Lukyantseva, V.I. Luzin, V.N. Morozov // Travma [Injury]. — 2014. — Vol. 15. — № 3. — P. 30–32. — EDN SNMKAB. [in Russian]

13. Amin K.A. Toxicological and safety assessment of tartrazine as a synthetic food additive on health biomarkers: A review / K.A. Amin, F.S. Al-Shehri // African Journal of Biotechnology. — 2018. — Vol. 17. — № 6. — P. 139–149. — DOI: 10.5897/AJB2017.16300.

14. Visweswaran B. Oxidative Stress by Tartrazine in the Testis of Wistar Rats / B. Visweswaran, G. Krishnamoorthy // Journal of Pharmacy and Biological Sciences. — 2012. — Vol. 2. — № 3. — P. 44–49. — DOI: 10.9790/3008-0234447.

15. Voronina T.A. Meksidol: osnovnye neiropsikhotropnye effekty i mekhanizm deistviya [Mexidol: main neuropsychotropic effects and mechanism of action] / T.A. Voronina // Farmateka [Pharmateca]. — 2009. — № 6 (180). — P. 28–31. — EDN KXDBCF. [in Russian]

16. Porokhovska N.V. Membranozashchitnye i antioksidantnye svoistva tiotriazolina v usloviyakh ostrogo immunokompleksnogo protsessa [Membrane protecting and antioxidative feature of thiotriazoline under conditions of acute immunocomplex process] / N.V. Porokhovska, M.S. Regeda // Jeksperimental'naja fiziologija i biohimija [Experimental Physiology and Biochemistry]. — 2007. — Vol. 3. — P. 35–39. [in Russian]