Ukrainian Journal of Ecology

Ukrainian Journal of Ecology, 2020, 10(6), 164-168, doi: 10.15421/2020_276

ORIGINAL ARTICLE

The effect of milk thistle, metiphen, and silimevit on the protein-synthesizing function of the liver of laying hens in experimental chronic cadmium toxicosis

M.I. Bashchenko[1], O.V. Boiko[1], O.F. Honchar[1], B.V. Gutyj[2]*, Y.V. Lesyk[3], A.Y. Ostapyuk[2], I.I. Kovalchuk[3], Kh.Ya. Leskiv[2]

[1]*Cherkassy experimental station of bioresources National academy of agricultural sciences of Ukraine, Cherkassy, Ukraine*

[2]*Stepan Gzhytskyi National University of Veterinary Medicine and Biotechnologies Lviv, Ukraine*

[3]*Institute of Animal Biology of NAAS, Lviv, Ukraine*

**Corresponding author E-mail: bvh@ukr.net*

Received: 18.10.2020. Accepted 29.11.2020

The study aimed to investigate the effect of milk thistle, methiphene, and silimevit on the liver's protein-synthesizing function of laying hens in examination chronic cadmium toxicosis. Thirty-two chickens, 78 weeks old, were selected for the study. Four groups were formed: control and three experimental. Birds of the experimental group (E_1) with fodder were fed the fruits of milk thistle at a dose of 2.0 g/kg of feed once a day for 30 days. Chickens of the experimental group ($E_{2)}$ were fed metifen at a dose of 0.28 g / kg of nutrition once a day for 30 days. Hens of the experimental group ($E_{3)}$ were fed silymevit at a dose of 0.36 g/kg of feed nutrition once a day for 30 days. The results showed that the total protein content and its plasma fractions of birds vary throughout the research in poultry control and experimental groups. Thus, in the blood of laying hens subjected to cadmium loading, a decrease in their blood of total protein and albumin fraction was found. Under the cadmium toxicosis of chickens, milk thistle, metifen, and silimevit positively affect the liver's protein-synthesizing function, as indicated by an increase in the total protein level and albumin. Feeding with milk thistle and silymevit contributed to a better normalizing effect on the liver's protein-synthesizing function than the use of metifen.

Keywords: toxicology, cadmium, poultry, blood, silymevit, metifen, milk thistle, total protein, albumins, proteins.

Introduction

The problem of cadmium pollution, which is one of the consequences of the intensification of industrial and agricultural production, has now become especially relevant (Vorozhenko & Skalskyi, 2011; Vishchur et al., 2019; Piven et al., 2020). The increase in the content of this metal in the soils of Ukraine and other countries over the past decades is accompanied by the accumulation of Cd_2^+ in agricultural products and feed, increasing the threat to human, animal, and poultry health (Uetani et al., 2005; Antoniak er al., 2010; Gutyj et al., 2016; 2017; 2019; Prysiazhniuk et al., 2019; Slivinska et al., 2020).

It is known that the intake of cadmium is associated with the environmental risk to the body due to its cumulative toxicity to organs and systems, leads to a decrease in growth rate and productivity of birds. This negatively affects the efficiency of the poultry industry. It requires an in-depth study of pharmaco-toxicological and biochemical processes underlying Cadmium-induced metabolic disorders of the bird's vital functions.

Cadmium poisoning of animals occurs when it enters the stomach or by inhalation into the respiratory tract (Al-Azemi et al., 2010; Lavryshyn & Gutyj, 2019). When ingested, cadmium inhibits mitochondria's activity while increasing the sensitivity of cells to free radical oxidation (Peng et al., 2015; Slobodian et al., 2019). Cadmium has a high migration rate, biochemical activity, polytropic toxicity, and the ability to accumulate in organs and tissues (Ali et al., 1986; Lavryshyn et al., 2019). It should be noted that about 50% of absorbed cadmium accumulates in the liver and kidneys. Intensive inclusion of cadmium in the liver and kidneys tissues is associated primarily with high activity of biochemical processes occurring in these organs (Slobodian et al., 2019; Gutyj et al., 2019).

The adverse effects of cadmium cover different cell types, but their sensitivity to this element's action is different (Fregoneze et al., 1997; El-Shahat et al., 2009). The depth of cell damage is mostly determined by the accumulated dose of cadmium and the level of expression of metallothionein genes in them, which is affected by the toxic element. Thus, cadmium effects are manifested in different ways under long-term and single entry into the animals' bodies (Rodríguez et al., 2001; Salvatori et al., 2004).

After oral absorption, cadmium is first transported through the portal vein to the liver, accumulates in hepatocytes, where it induces the synthesis of metallothioneins. Which, in turn, reduces the toxic effects of cadmium in the kidneys and liver (Lu et al., 2005; Liu et al., 2008). The intensity of metallothionein synthesis in hepatocytes in response to the influx of cadmium ions is higher than in other cells. Histological changes in the liver in cadmium toxicosis are represented by dystrophy manifestations, apoptosis, and inflammatory response. Dystrophic processes were manifested by hydropic dystrophy with vacuolation of the cytoplasm of hepatocytes, in places to focal colic necrosis (Gutyj et al., 2019).

Cadmium's indirect hepatotoxic effect is due to Kupffer cells' activation, which triggers a cascade of biochemical processes involving many cytokines and inflammatory mediators (Melnychuk et al., 2004; Khariv et al., 2017).

The study aimed to investigate the effect of milk thistle, methiphene, and silimevit on the liver's protein-synthesizing function of laying hens in experimental chronic cadmium toxicosis.

Materials and methods

Thirty-two chickens, 78 weeks old, were selected for the study. Four groups were formed: control and three experimental. Birds of the experimental group (E_1) with fodder were fed the fruits of milk thistle at a dose of 2.0 g/kg of feed once a day for 30 days. Chickens of the experimental group ($E_{2)}$ were fed metifen at a dose of 0.28 g/kg of nutrition once a day for 30 days. Hens of the experimental group ($E_{3)}$ were fed silymevit at a dose of 0.36 g/kg of feed nutrition once a day for 30 days.

The conditions of keeping chickens and the microclimate parameters in the room for all groups were similar. The amount of feed and water consumed was taken into account during the test.

All experimental interventions and slaughter of animals were carried out in compliance with the European Convention's requirements for the Protection of Vertebrate Animals Used for Experimental and Scientific Purposes (Strasbourg, 1985) and the decision of the First National Congress on Bioethics (Kyiv, 2001).

Blood from birds was collected from the vein under the wing in the periods: before administering drugs and cadmium sulfate, on the first, seventh, fourteenth, twenty-first, and thirtieth days of the test. The protein concentration and its fractions were studied according to the method (Vlizlo, 2012).

The analyses used the following drugs:

Cadmium sulfate - Cadmium sulfate is an inorganic compound with the chemical formula $CdSO_4$. Cadmium sulfate is well soluble in water, so it is well absorbed in the digestive tract, blood and is known for its toxic effects on living organisms.

Milk thistle (MT) – Silybum marianum is a family of compound flowers, grows wild in wastelands, along roads, abandoned fields, and it is cultivated in medicinal gardens. Milk thistle fruits are uses for treatment. They contain 17-18% protein, 10-11% fat, 2-3% flavonolignans, 0.08% essential oil, vitamins A, E, K, nutrients, quercetin.

Metifen (M) is a white crystalline powder, sweet in taste, with the smell of sulfur. Poorly soluble in cold water, better – In hot water (1:20). Thermostable. The drug contains phenarone and methionine.

Silymevit (S) – feed additive, which includes the fruits of milk thistle, selenium, methiphen, vitamins A, E and C (Sobolev et al., 2017; 2020; Ostapyuk & Gutyj, 2020; Martyshuk et al., 2020).

The analysis of research results was performed using the software package Statistica 6.0. The Student's t-test assessed the probability of differences. The results of the mean values were considered statistically significant at * - P<0.05, ** - P<0.01, *** - P<0.001 (ANOVA).

Results and discussion

To analyze the mechanism of action of milk thistle, methiphen, and silimevit on the body of chickens of the required values, the state of metabolic processes is examined. The obtained results of biochemical studies of the blood of laying hens for cadmium loading indicate a violation of the liver's protein-synthesizing function. Our research outcomes showed that the content of total protein and its plasma fractions were performed during a general analysis in the control group and experimental groups. Thus, in the blood of laying hens that carry out cadmium loading, a decrease in their blood total protein to 39.04±1.23 g/l (Table 1).

Table 1. The total protein level in the blood of laying hens after the administration of milk thistle, methiphen, and silimevit in chronic cadmium toxicosis (M±m, n=8)

Blood test time (days)	Total protein (g/l) Groups of chickens			
	Control (cadmium)	Experimental 1 (cadmium + MT)	Experimental 2 (cadmium + M)	Experimental 3 (cadmium + S)
At the beginning of the experiment	46.58±1.06	46,52±1,05	46,60±0,90	46,45±1,00
the first day	45.74±1.10	46.28±1.14	46.37±1.24	46.32±1.15
the 7 th day	44.62±0.96	45.21±1.20	45.05±1.11	45.45±1.24
the 14 th day	42.31±1.15	44.95±1.18	44.75±1.22	45.76±1.20*
the 21 th day	39.04±1.23	45.55±1.06**	45.34±1.18**	46.39±1.21***
the 30 th day	39.65±1.11	46.10±1.25**	45.93±1.20**	46.51±1.30***

In the E_2 group's chickens, the total protein level on the 7th day was 46.28±1.14 g/l. Slightly higher levels were in the experimental groups of chickens fed methiphene and silimevit. In chickens of test group E_2, the total protein level on the 7th day was 46.28±1.14 g/l. On the 14th day of the research, the total protein level compared with the C group of chickens increased in the group E_1 by 6.2% in the E_2 group – by 5.8% and in the E_3 group – by 8.2%, respectively. On the 1st day of the test, the total protein level in the experimental groups of chickens fed milk thistle and methiphen was in the range of 45.55±1.06 – 45.34±1.18 g/l. The highest level of the studied indicator was in the group of hens fed silimevit. Compared to the C group of birds, it increased by 19%. On the 30th day of the search, all test groups' total protein level was within physiological values.
Similar changes were observed in the examination of albumin content (Table 2). In laying hens of the C group, the rate on the 14th day of was lower than the initial rate by 4.16%, on the 21st day by 5.62%, and on the 30th day – by 3.58%

Table 2. The albumin level in the blood of laying hens after the administration of milk thistle, metiphen, and silimevit in chronic cadmium toxicosis (M±m, n=8)

Blood test time (days)	Albumins (%) Groups of chickens			
	Control (cadmium)	Experimental 1 (cadmium + MT)	Experimental 2 (cadmium + M)	Experimental 3 (cadmium + S)
At the beginning of the experiment	33.78±0.93	33.92±0.90	33.85±0.94	33,74±0,70
the first day	32.92±0.93	33.23±0.84	33.41±0.93	33.68±0.91
the 7 th day	31.84±0.89	32.53±0.94	32.36±0.82	32.83±0.75
the 14 th day	29.62±0.98	31.26±0.90*	31.11±0.94	32.91±0.95*
the 21 th day	28.16±0.75	32.82±0.79***	32.64±0.95***	33.69±0.67***
the 30 th day	29.34±0.97	33.26±0.90**	33.10±0.85**	33.80±0.84**

The albumin level in the blood of chickens of the experimental groups at the beginning of the test ranged from 33.92±0.90 to 33.74±0.70%. On the first day, the level of albumin in all groups decreased slightly. Subsequently, on the 7th and 14th day of the, the level of albumin in the blood of E_1 group and E_2 reduced compared with the beginning, but with the C group of chickens increased by 0.69 and 1.64% in the E_1 group and 0.52 and 1.49% in the E_2 group.
At cadmium loading of laying hens with simultaneous feeding of silimevit, the normalizing effect of the drug on the level of albumin in the blood of chickens of the E_3 group was established. During the whole experiment ranged from 32.83±0.75 to 33.80±0.84%. A significant difference between the birds of the control and experimental groups was observed analyzing the indicators of total protein and protein fractions in the blood plasma of laying hens under cadmium loading and the use of drugs from 14 days of the research.
In the investigation of the globulin fraction in the blood of laying hens, its progress was found only in the control group of chickens subjected to cadmium loading. On days 14 and 21, the globulins level in the blood of the C group of birds increased by 4.16 and 5.62%. When feeding laying hens of milk thistle, metiphene and silimevit, a slight increase in the globulin fraction was found on the first and seventh days. On the 14th day of the search, the globulins level in the blood of the E_1 group and E_2 was 68.74±1.84 and 68.89±2.06%. This figure was significantly higher in the C group and was respectively 70.38±1.85%. In the blood of laying hens fed with cadmium sulfate silimevit, a lower level of globulins was found during this experiment, namely 67.09±1.96%. On days 21 and 30 of the practice, the globulins' level in the blood of the first two experimental groups, fed milk thistle and metiphen, declined but did not reach the initial conditions. Only in chickens of the E_3 group, which was provided silymevit, the globulin fraction level was reduced to the level of initial values.

Table 3. The globulins level in the blood of laying hens after the administration of milk thistle, metiphen, and silimevit in chronic cadmium toxicosis (M±m, n=8)

Blood test time (days)	Globulins (%) Groups of chickens			
	Control (cadmium)	Experimental 1 (cadmium + MT)	Experimental 2 (cadmium + M)	Experimental 3 (cadmium + S)
At the beginning of the experiment	66.22±1.87	66.08±1.56	66.15±2.00	66.26±1.80
the first day	67.08±1.90	66.77±1.76	66.59±2.04	66.32±2.01
the 7 th day	68.16±2.35	67.47±1.96	67.64±1.99	67.17±1.85
the 14 th day	70.38±1.85	68.74±1.84	68.89±2.06	67.09±1.96
the 21 th day	71.84±2.10	67.18±1.93*	67.36±2.10	66.31±2.05*
the 30 th day	70.66±1.95	66.74±1.87	66.90±1.82	66.20±2.11*

Diminished albumin content with a simultaneous increase in the level of globulin fraction is assessed as dysproteinemia due to impaired liver protein-necrosis function on the one hand. On the other hand, the impaired absorption of protein breakdown products from the small intestine is due to mucosal toxin damage.

Conclusions

Under the cadmium load of laying hens, milk thistle, metifen and silimevit have a positive effect on the liver's protein-synthesizing function, as indicated by an increase in the total level of protein and albumin.

Feeding with milk thistle and silymevit food contributed to a better normalizing effect on the liver's protein-synthesizing function than the use of metifen.

Acknowledgments

This scientific work was financially supported by the Ministry of Education and Science of Ukraine (0120U101999)

References

Al-Azemi, M., Omu, F.E., Kehinde, E.O., Anim, J.T., Oriowo, M.A., & Omu, A.E. (2010). Lithium protects against toxic effects of cadmium in the rat testes. J. Assist. Reprod. Genet, 27 (8), 469–476. doi: 10.1007/s10815-010-9426-3.

Ali, M. M., Murthy, R. C., & Chandra, S. V. (1986). Developmental and longterm neurobehavioral toxicity of low-level in utero Cd exposure in rats. Neurobehavioral Toxicology and Teratology, 8 (5), 463–468. URL: https://www.ncbi.nlm.nih.gov/pubmed/3785508.

Antoniak, H. L., Biletska, L. P., & Babych, N. A. (2010). Kadmii v orhanizmi liudyny i tvaryn. Nadkhodzhennia do klityn i yikh akumuliatsiia. Biolohichni Studii. Studia Biologica, 4 (2), 127–140 (in Ukrainian).

El-Shahat, A. E., Gabr, A., Meki, A. R., & Mehana, E. S. (2009). Altered testicular morphology and oxidative stress induced by cadmium in experimental rats and protective effect of simultaneous green tea extract. Int. J. Morphol., 27(3), 757–764. doi: 10.4067/S0717-95022009000300020.

Fregoneze, J. B., Marinho, C. A., Soares, T., Castro, L., Sarmento, C., Cunha, M., Gonzalez, V., Oliveira, P., Nascimento, T., Luz, C.P., Santana, Jr. P., De-Oliveira, I.R., & e-Castro-e-Silva, E. (1997). Lead (Pb2+) and cadmium (Cd2+) inhibit the dipsogenic action of central beta-adrenergic stimulation by isoproterenol. Brazilian Journal of Medical and Biological Research, 30(3), 419–423. doi: 10.1590/S0100-879X1997000300018.

Gutyj, B. V., Murs'ka, S. D., Gufrij, D. F., Hariv, I. I., Levkivs'ka, N. D., Nazaruk, N. V., Gajdjuk, M. B., Pryjma, O. B., Bilyk, O. Ja., & Guta, Z. A. (2016). Influence of cadmium loading on the state of the antioxidant system in the organism of bulls. Visnyk of Dnipropetrovsk University. Biology, ecology, 24(1), 96–102. doi: 10.15421/011611.

Gutyj, B. V., Ostapyuk, A. Y., Sobolev, O. I., Vishchur, V. J., Gubash, O. P., Kurtyak, B. M, Kovalskyi, Y. V., Darmohray, L. M., Hunchak, A. V., Tsisaryk, O. Y., Shcherbatyy, A. R., Farionik, T. V., Savchuk, L. B., Palyadichuk, O. R., & Hrymak, K. (2019). Cadmium burden impact on morphological and biochemical blood indicators of poultry. Ukrainian Journal of Ecology, 9(1), 236-239

Gutyj, B., Grymak, Y., Drach, M., Bilyk, O., Matsjuk, O., Magrelo, N., Zmiya, M., & Katsaraba, O. (2017). The impact of endogenous intoxication on biochemical indicators of blood of pregnant cows. Regulatory Mechanisms in Biosystems, 8(3), 438–443. doi: 10.15421/021768

Gutyj, B., Leskiv, K., Shcherbatyy, A., Pritsak, V., Fedorovych, V., Fedorovych, O., Rusyn, V., & Kolomiiets, I. (2017). The influence of Metisevit on biochemical and morphological indicators of blood of piglets under nitrate loading. Regulatory Mechanisms in Biosystems, 8(3), 427–432. doi: 10.15421/021766

Gutyj, B., Nazaruk, N., Levkivska, A., Shcherbatyj, A., Sobolev, A., Vavrysevych, J., Hachak, Y., Bilyk, O., Vishchur, V., Guta, Z. (2017). The influence of nitrate and cadmium load on protein and nitric metabolism in young cattle. Ukrainian Journal of Ecology, 7(2), 9–13.

Gutyj, B., Ostapiuk, A., Kachmar, N., Stadnytska, O., Sobolev, O., Binkevych, V., Petryshak, R., Petryshak, O., Kulyaba, O., Naumyuk, A., Nedashkivsky, V., Nedashkivska, N., Magrelo, N., Golodyuk, I., Nazaruk, N., & Binkevych, O. (2019). The effect of cadmium loading on protein synthesis function and functional state of laying hens' liver. Ukrainian Journal of Ecology, 9(3), 222-226

Gutyj, B., Stybel, V., Darmohray, L., Lavryshyn, Y., Turko, I., Hachak, Y., Shcherbatyy, A., Bushueva, I., Parchenko, V., Kaplaushenko, A., Krushelnytska, O. (2017). Prooxidant-antioxidant balance in the organism of bulls (young cattle) after using cadmium load. Ukrainian Journal of Ecology, 7(4), 589–596.

Khariv, M., Gutyj, B., Ohorodnyk, N., Vishchur, O., Khariv, I., Solovodzinska, I., Mudrak, D., Grymak, C., & Bodnar, P. (2017). Activity of the T- and B-system of the cell immunity of animals under conditions of oxidation stress and effects of the liposomal drug. Ukrainian Journal of Ecology, 7(4), 536–541

Lavryshyn, Y., & Gutyj, B. (2019). Protein synthesize function of bulls liver at experimental chronic cadmium toxicity. Scientific Messenger of LNU of Veterinary Medicine and Biotechnologies. Series: Veterinary Sciences, 21(94), 92–96. doi: 10.32718/nvlvet9417.

Lavryshyn, Y., Gutyj, B., Paziuk, I., Levkivska, N., Romanovych, M., Drach, M., & Lisnyak, O. (2019). The effect of cadmium loading on the activity of the enzyme link of the glutathione system of bull organism. Scientific Messenger of LNU of Veterinary Medicine and Biotechnologies. Series: Veterinary Sciences, 21(95), 107–111. doi: 10.32718/nvlvet9520.

Liu, J., Qian, S.Y., Guo, Q., Jiang, J., Waalkes, M.P., Mason, R.P., & Kadiiska, M.B. (2008). Cadmium generates reactive oxygen- and carbon-centered radicalspecies in rats: Insights from in vivo spin-trappingstudies. Free Radic Biol Med., 45 (4), 475–481. doi: 10.1016/j.freeradbiomed.2008.04.041.

Lu, J., Jin, T., Nordberg, G., & Nordberg, M. (2005). Metallothionein gene expression in peripheral lymphocytes and renal dysfunction in a population environmentally exposed to cadmium. Toxicol. Appl. Pharmacol., 206 (2), 150–156. doi: 10.1016/j.taap.2004.12.015.

Martyshuk, T. V., Gutyj, B. V., Zhelavskyi, M. M., Midyk, S. V., Fedorchenko, A. M., Todoriuk, V. B., Nahirniak, T. B., Kisera, Ya. V., Sus, H. V., Chemerys, V. A., Levkivska, N. D., & Iglitskej, I. I. (2020). Effect of Butaselmevit-Plus on the immune system of piglets during and after weaning. Ukrainian Journal of Ecology, 10(2), 347–352. doi: 10.15421/2020_106

Melnychuk, D. O., Melnykova, N. M., & Derkach, Ye. A. (2004). Vikovi osoblyvosti kumuliatsii kadmiiu v orhanakh otruienykh shchuriv i zminy pokaznykiv kyslotnoluzhnoho stanu krovi za riznykh umov antyoksydantnoho zakhystu orhanizmu. Ukrainskyi biokhimichnyi zhurnal, 95–99 (in Ukrainian).

Ostapyuk, A. Y., & Gutyj, B. V. (2020). Influence of milk thistle, methifene and sylimevit on the morphological parameters of laying hens in experimental chronic cadmium toxicosis. Ukrainian Journal of Veterinary and Agricultural Sciences, 3(1), 42–46. doi: 10.32718/ujvas3-1.08

Peng, L., Wang, X., Huo, X., Xu, X., Lin, K., Zhang, J., Huang, Y., & Wu, K. (2015). Blood cadmium burden and the risk of nasopharyngeal carcinoma: a case–control study in Chinese Chaoshan population. Environmental Science and Pollution Research, 22(16), 12323–12331. doi: 10.1007/s11356-015-4533-4.

Piven, O. T., Khimych, M. S., Salata, V. Z., Gutyj, B. V., Naidich, O. V., Skrypka, H. A., Koreneva, Z. B., Dvylyuk, I. V., Gorobey, O. M., Rud, V. O. (2020). Contamination of heavy metals and radionuclides in the honey with different production origin. Ukrainian Journal of Ecology, 10(2), 405–409.

Prysiazhniuk, N., Grynevych, N., Slobodeniuk, O., Kuzmenko, O., Tarasenko, L., Bevz, O., Khomiak, O., Horchanok, A., Gutyj, B., Kulyaba, O., Sachuk, R., Boiko, O., & Magrelo, N. (2019). Monitoring of morphological parameters of Cyprinidae liver. Ukrainian Journal of Ecology, 9(3), 162–167.

Rodríguez, E. M., Bigi, R., Medesani, D. A., Stella, V. S., Greco, L. S. L., Moreno, P. A. R., Monserrat, J. M., Pellerano, G. N., & Ansaldo, M. (2001). Acute and chronic effects of cadmium on blood homeostasis of an estuarine crab, Chasmagnathus granulata, and the modifying effect of salinity. Brazilian Journal of Medical and Biological Research, 34(4), 509–518. URL: https://www.ncbi.nlm.nih.gov/pubmed/11285463.

Salvatori, F., Talassi, C. B., Salzgeber, S. A., Sipinosa, H. S., & Bernardi, M. M. (2004). Embryotoxic and long-term effects of cadmium exposure during embryogenesis in rats. Neurotoxicology and Teratology, 26(5), 673–680. doi: 10.1016/j.ntt.2004.05.001.

Slivinska, L. G., Shcherbatyy, A. R., Lukashchuk, B. O., & Gutyj, B. V. (2020). The state of antioxidant protection system in cows under the influence of heavy metals. Regulatory Mechanisms in Biosystems, 11(2), 237–242. doi:10.15421/022035

Slobodian, S. O., Gutyj, B. V., & Leskiv, K. Y. (2019). The level of lipid peroxidation products in the rats blood under prolonged cadmium and lead loading. Ukrainian Journal of Veterinary and Agricultural Sciences, 2(3), 15–18. doi: 10.32718/ujvas2-3.04

Sobolev, O. I., Gutyj, B. V., Sobolieva, S. V., Borshch, O. O., Kushnir, I. M., Petryshak, R. A., Naumyuk, O. S., Kushnir, V. I., Petryshak, O. Y., Zhelavskyi, M. M., Todoriuk, V. B., Sus, H. V., Levkivska, N. D., Vysotskij, A. O., & Magrelo, N. V. (2020). Review of germanium environmental distribution, migration and accumulation. Ukrainian Journal of Ecology, 10(2), 200–208. doi: 10.15421/2020_86

Sobolev, O. I., Gutyj, B. V., Sobolieva, S. V., Borshch, O. O., Nedashkivsky, V. M., Kachan, L. M., Karkach, P. M., Nedashkivska, N. V., Poroshinska, O. A., Stovbetska, L. S., Emelyanenko, A. A., Shmayun, S. S., & Guta, Z. A. (2020). Selenium in natural environment and food chains. A Review. Ukrainian Journal of Ecology, 10(4), 148–158.

Sobolev, A., Gutyj, B., Grynevych, N., Bilkevych, V., & Mashkin, Y. (2017). Enrichment of meat products with selenium by its introduction to mixed feed compounds for birds. Regulatory Mechanisms in Biosystems, 8(3), 417–422. doi: 10.15421/021764

Uetani, M., Kobayashi, E., Suwazono, Y., Okubo, Y., Honda, R., Kido, T., & Nogawa, K. (2005). Selenium, Cadmium, Zinc, Copper, and Iron Concentrations in Heart and Aorta of Patients Exposed to Environmental Cadmium. Bulletin of Environmental Contamination and Toxicology, 75 (2), 246–250. doi: 10.1007/s00128-005-0744-6.

Vishchur, V. Y., Gutyj, B. V., Nischemenko, N. P., Kushnir, I. M., Salata, V. Z., Tarasenko, L. O., Khimych, M. S., Kushnir, V. I., Kalyn, B. M., Magrelo, N. V., Boiko, P. K., Kolotnytskyy, V. A., Velesyk, T., Pundyak, T. O., Gubash, O. P. (2019). Effect of industry on the content of fatty acids in the tissues of the honey-bee head. Ukrainian Journal of Ecology, 9(3), 174–179.

Vlizlo, V. V. (2012). Laboratorni metody doslidzhen u biolohiyi, tvarynnytstvi ta veterynarniy medytsyni. Spolom, Lviv (in Ukrainian).

Vorozhenko, V. V., & Skalskyi, Yu. M. (2011). Hihiienichna otsinka ryzykiv vplyvu neradiatsiinykh antropohennykh chynnykiv na stan zdorovia naselennia Ukrainy. Odeskyi medychnyi zhurnal, 5(127), 4–8 (in Ukrainian).

Citation:

Bashchenko, M.I., Boiko, O.V., Honchar, O.F., Gutyj, B.V., Lesyk, Y.V., Ostapyuk, A.Y., Kovalchuk, I.I., Leskiv, Kh.Ya. (2020). The effect of milk thistle, metiphen, and silimevit on the protein-synthesizing function of the liver of laying hens in experimental chronic cadmium toxicosis. *Ukrainian Journal of Ecology, 10*(6), 164-168.