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ACCUMULATION OF ^{137}Cs , Pb, Cd, Cu IN THE MUSCLE TISSUE AND LIVER OF PIGS GETTING DIFFERENT RATIONS

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Experimental studies on young pigs of the large white breed were conducted on the territory of the physiological yard of the Polissia Institute of Agriculture of the National Academy of Sciences (III zone of radioactive contamination due to the accident at the Chernobyl Nuclear Power Plant). To conduct the experiment, 2 groups of experimental animals were formed: Group I (control) was fed with grain mixture № 1 with narrow-leaved lupine (alkaloid-free) and sunflower cake; II group (experimental) received grain mixture № 2 with genetically modified soy. Experimental pigs were kept in one room according to the accepted technology in group cages equipped with a wooden floor. The mode of feeding and drinking, parameters of the microclimate in both groups were the same.

*According to the results of tests conducted at the Ukrainian Laboratory of Quality and Safety of Agricultural Products, it was established that soybeans contain genetically modified deoxyribonucleic acid (DNA), have the target sequence of the 35S+FMV promoter of the cauliflower mosaic virus and the NOS terminator (nopaline synthase) of *Agrobacterium tumefaciens*.*

The specific activity of ^{137}Cs in the longest back muscle of pigs varied by group within 3.7-10.3 Bq/kg and did not exceed permissible levels (DR-2006 = 200 Bq/kg). When used as part of the GM soybean grain mixture, the concentration of radiocesium in the muscle tissue of animals of the II (experimental) group relative to the control decreased by 6.6 Bq/kg, or by 64.1% with a statistically significant difference ($P > 0.95$). Moreover, the accumulation rate of ^{137}Cs in the longest back muscle of piglets was 0.46-0.95 and was 2.1 times higher in young pigs that received grain mixture No. 1 without GM soybeans, compared to the use of grain mixture No. 2.

The concentration of Pb in the slaughter products of experimental animals was significantly lower than the MPC, while the level of contamination of the longest back muscle of pigs Cd exceeded the regulatory requirements by 1.40-1.44 times. The introduction of 60% (by mass) of corn grain and 10% of GM soybeans into the grain mixture instead of the same amount of wheat grain, lupine and sunflower cake for fattening young pigs in the III zone of radioactive pollution contributes to a smaller accumulation of heavy metals in meat: Pb – by 17.5%, Cd – by 2.8%, Cu – by 4.2%. Therefore, the transition coefficients of Pb and Cd into the muscle tissue of animals of the II (experimental) group relative to the analogues of the I (control) group increased by 1.24% and 3.02% respectively, and Cu decreased by 0.23%.

Key words: pigs, ^{137}Cs , Pb, Cd, Cu. GM soy, the longest back muscle, liver.



НАКОПИЧЕННЯ ^{137}Cs , Pb , Cd , Cu У М'ЯЗОВІЙ ТКАНИНІ І ПЕЧІНЦІ СВИНЕЙ ЗА ВИКОРИСТАННЯ РІЗНОТИПОВИХ РАЦІОНІВ

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Експериментальні дослідження на молодняку свиней великої білої породи проводили на території фізіологічного двору Інституту сільського господарства Полісся НААН (III зона радіоактивного забруднення внаслідок аварії на ЧАЕС). Для проведення дослідів сформовано 2 групи піддослідних тварин: I група (контрольна) – згодовували зерносуміш №1 з люпином вузьколистим (безалкалоїдним) і макухою соняшниковою; II група (дослідна) – отримувала зерносуміш №2 з генетично модифікованою соєю. Піддослідних свиней утримували в одному приміщенні згідно з прийнятою технологією – у групових клітках, обладнаних дерев'яною підлогою. Режим годівлі та напування, параметри мікроклімату в обох групах були однаковими.

За результатами випробувань, проведених в Українській лабораторії якості і безпеки продукції АПК, встановлено, що соя містить генетично модифіковану дезоксирибонуклеїнову кислоту (ДНК), має цільову послідовність промотора 35S+FMV вірусу мозаїки цвітної капусти та NOS-термінатора (нопалінсинтази) *Agrobacterium tumefaciens*.

Питома активність ^{137}Cs в найдовшому м'язі спини свиней коливалася по групах у межах 3,7-10,3 Бк/кг і не перевищувала допустимих рівнів (ДР-2006 = 200 Бк/кг). За використання у складі зерносуміші ГМ-сої, концентрація радіоцезію в м'язовій тканині тварин II (дослідної) групи відносно контролю знижувалася на 6,6 Бк/кг, або на 64,1 % за статистично значущої різниці ($P > 0,95$). Водночас кратність накопичення ^{137}Cs в найдовшому м'язі спини підсвинків складала 0,46-0,95 і була більшою у 2,1 рази в молодняку свиней, які отримували зерносуміш №1 без ГМ-сої, порівняно з використанням зерносуміші №2.

Концентрація Pb в продуктах забою піддослідних тварин була значно нижчою за ГДК, тоді як рівень забруднення найдовшого м'язу спини свиней Cd перевищував нормативні вимоги в 1,40-1,44 рази. Уведення до складу зерносуміші 60 % (за масою) дерті кукурудзи і 10 % ГМ-сої замість аналогічної кількості дерті пшениці, люпину і макухи соняшникової за відгодовлі молодняку свиней у III зоні радіоактивного забруднення сприяє меншому нагромадженню важких металів у м'ясі: Pb – на 17,5 %, Cd – 2,8, Cu – на 4,2 %. При цьому коефіцієнти переходу Pb і Cd у м'язову тканину тварин II (дослідної) групи відносно аналогів I (контрольної) групи підвищувалися на 1,24 % і 3,02 % абс. відповідно, а Cu – знижувалися на 0,23 % абс..

Ключові слова: свині, ^{137}Cs , Pb , Cd , Cu . ГМ-соя, найдовший м'яз спини, печінка.

Introduction. As a result of the accident at the Chernobyl NPP, large areas of Ukrainian Polissia were contaminated with radioactive substances ^{137}Cs , ^{90}Sr , etc. Their entry into the body of animals with fodder rations requires the use of technologies for the production of livestock products that make it possible to produce ecologically safe



and high-quality food products for the population living in these regions (Zubets M.V. et al., 2011; Krasnov V.P. et al., 2015). Regardless of the general trend of stabilization of the radiation state, it should be noted that the levels of radioactive contamination of agricultural products in some regions of Polissia of Ukraine are ten times higher than the pre-accident level and in some cases, especially in peasant farms, remain significantly higher compared to the existing regulations (Romanchuk L. D. et al., 2019).

Pollution of the Polissia zone by heavy metals such as Pb, Cd, Cu remains an equally important problem (Savchuk I. et al., 2022). These chemical elements and their compounds are toxic in high concentrations, which negatively affect the health, productivity of animals, and the quality of livestock products (Peng L. et al., 2015; Martyshuk T.V. et al., 2019).

Heavy metals are metallic elements with a high density that gradually accumulate in the food chain with negative effects on human health. Some elements are necessary (Fe, I, Co, Zn, Cu, Mn, Mo, Se) to support various physiological functions and are usually added as feed additives to the ration of animals. Other metals (Cd, Pb, Hg) have no established biological functions and are considered pollutants (Hejna M. et al., 2018). Heavy metals are potentially dangerous due to their toxicity, bioaccumulation and biomagnification when they are in living tissues and accumulate more than they are excreted (Jarup L., 2003).

According to the authors (Mamenko O.M., Portiannik S.V., 2021), in areas with high anthropogenic pressure, in order to reduce the accumulation of harmful substances in the body of animals and obtain ecologically safe livestock products, it is very important to balance the rations of animals in terms of protein, trace elements and vitamins. It was established that with a shortage of sugar, protein, and mineral substances in the rations, and, as a result, low productivity of animals, the accumulation of ^{137}Cs and heavy metals in milk and meat increases significantly compared to complete feeding. Complete protein nutrition weakens the toxic effect of harmful substances, reduces the absorption of ^{137}Cs and heavy metals from the gastrointestinal tract and increases their removal from the body (Razanov S. et al., 2022).

Taking into account the wide range of biological and toxic effects of radionuclides and heavy metals, which causes a negative impact on the internal organs and systems of animals (Roggeman S. et al., 2014; Hashemi S., 2018), it is worth noting that the necessity of improving the system of management of the livestock industry and animal feeding in areas of increased man-made load of agricultural production. Therefore, research on the search for types of feed and rations of animals with the aim of reducing the accumulation of ^{137}Cs , Pb, Cd, Cu in livestock products during their production in the III zone of radioactive contamination due to the accident at the Chernobyl nuclear power plant is quite relevant.

The purpose of the research is to determine the accumulation and transfer of ^{137}Cs , Pb, Cd, Cu in the muscle tissue and liver of pigs when using different high-protein feeds in the composition of fodder grain such as narrow-leaved lupine and sunflower meal and GM soybeans.

Research materials and methods. Experimental studies on young pigs of the large white breed were conducted on the territory of the physiological yard of the Polissia Institute of Agriculture of the National Academy of Sciences. To conduct the experiment, 2 groups of young pigs were formed using the method of balanced groups according to the methodological provisions of Ibatullin I.I. and Zhukorskyi O.M. (2017). The average indicators by which the animals were characterized were almost equal in both groups. Experimental pigs were kept in one room according to the accept-



ed technology in group cages equipped with a wooden floor. The mode of feeding and drinking, parameters of the microclimate in both groups were the same.

According to the scheme of the experiment, during the comparative period, the animals of both experimental groups received grain mixture No. 1, which consisted of concentrated fodder of local production, grown in the III zone of radioactive contamination, with the addition of PMVA (Table 1).

Table 1

The composition of grain mixtures during research, % by mass

Concentrated fodder	Grain mixture № 1	Grain mixture № 2
Wheat grain	60	-
Corn grain	-	60
Triticale grain	25	25
Sunflower cake	5	-
Narrow-leaved lupine (alkaloid-free)	5	-
GM soybeans extruded	-	10
PMVA	5	5
In total	100	100

The difference in the feeding of the experimental pigs in the main period of the research was that the animals of the I (control) group received the same feed as in the comparative period of the experiment. Simultaneously, in the II (experimental) group of piglets, 60% of wheat grain (by weight) in the ration was replaced by 60% of corn grain, and 10% of cake and lupine – with a similar amount of genetically modified extruded soybeans.

On average, the animals consumed slightly different amounts of mixed grain per day: I group – 2.52 kg, II group – 2.29 kg. The nutritional value of 1 kg of fodder for piglets was also different: I group – 1.16 ECO, 11.6 MJ of exchangeable energy and 869 g of dry matter; II group – 1.36 ECO, 13.6 MJ of exchangeable energy and 866 g of dry matter. During the period of raising young pigs, the concentration of energy in 1 kg of dry matter of the ration was: I group – 1.33 ECO and 13.3 MJ of exchangeable energy, II group – 1.57 ECO and 15.7 MJ of exchangeable energy. Based on the calculation of 1 kg of dry matter of the ration, there were 155-121 g of digestible protein (norm 109-118 g) and 42.5-64.5 g of fiber, which is slightly lower than the existing norms for fattening pigs (norm 66-76 g) (I.I. Ibatullin, O.M. Zhukorskyi, 2016).

Determination of the specific activity of ^{137}Cs in feed and livestock products was carried out on a SEG-0.5 spectrometer. The preparation of samples of plant and animal origin for the determination of heavy metals in their composition was carried out by the method of dry mineralization, the analysis was carried out on the atomic absorption spectrometer "Kvant-2A" according to DSTU 7670:2014.

Transition coefficients (CP) of heavy metals (Pb, Cd, Cu) in the "ration – production (muscle tissue and liver)" chain were determined by the formula: $\text{TC} = \text{Chmp.}/\text{Chmr.} \times 100$, where TC is the transition coefficient; Chmp is the content of heavy metals in animal products, mg/kg; Chmr is the content of heavy metals in the daily ration, mg (Mamenko O.M., Portyanyk S.V., 2019). This coefficient is a relative integrated indicator, which in % reflects the migration of heavy metals from the ration to products, which allows for a comparative assessment of the transfer of pollutants when using different fodder mixtures for feeding pigs.



Research results. In the conditions of modern man-made pollution of the environment, ecological problems, improvement of the quality of livestock products and their food safety become extremely relevant.

The specific activity of ¹³⁷Cs in the fodder of the rations fluctuated within insignificant limits 8.0-10.8 Bq/day and was greater by 2.8 Bq/day or by 35.0% in the I (control) group than in the II (experimental) group. This is due to the consumption of experimental pig herds of grain mixes of different composition. Probably, the accumulation of radionuclide in winter wheat and lupine compared to corn and GM soybeans was significantly greater.

According to the research results, a significant intergroup difference in the concentration of ¹³⁷Cs in the longest back muscle and an improbable difference in the liver of the experimental young pigs were established (Table 2).

Table 2

Concentration of ¹³⁷Cs in ration feed and products (n=3; M ± m)

Groups of animals	¹³⁷ Cs concentration			
	average daily ration, Bq	products, Bq/kg	± to control group	
			Bq/kg	%
The longest back muscle				
I - control	10.8	10.3 ± 1.8	-	-
II - experimental	8.0	3.7 ± 0.3*	-6.6	-64.1
Liver				
I - control	10.8	6,0 ± 1,7	-	-
II - experimental	8.0	4.0 ± 1.0	-2.0	-33.3

Note. * - P>0.95

The specific activity of ¹³⁷Cs in the longest back muscle of the animals ranged from 3.7 to 10.3 Bq/kg and did not exceed permissible levels (DR-2006 = 200 Bq/kg). Therefore, when grain mixture No. 2 is used as part of the ration, the concentration of radiocesium in the muscle tissue of young pigs of the II (experimental) group, relative to the control, decreases by 6.6 Bq/kg, or by 64.1% (P>0.95).

A similar pattern was observed in the accumulation of ¹³⁷Cs in the liver of experimental young pigs as this indicator was the lowest in animals of II group (4.0 Bq/kg), and the highest in the analogues of I group (6.0 Bq/kg). Compared to the longest back muscle, the concentration of ¹³⁷Cs in the liver of animals of the control group was lower by 41.7%, while this indicator was higher by 8.1% when pigs were fed with grain-mix № 2.

The parameter that characterizes contamination of animal husbandry products with radionuclides depending on their entry into the body of animals with feed is the multiplicity of accumulation. This is the ratio of the nuclide content in an organ, tissue or organism as a whole to the content in the daily ration (B.S. Priester, 2007).

In our studies, the accumulation rate of ¹³⁷Cs in the longest back muscle was 0.46-0.95 and was 2.1 times higher in young pigs that received grain mixture № 1 with wheat, lupine and cake, compared to grain mixture No. 2 with corn and genetically modified soy (Fig. 1).

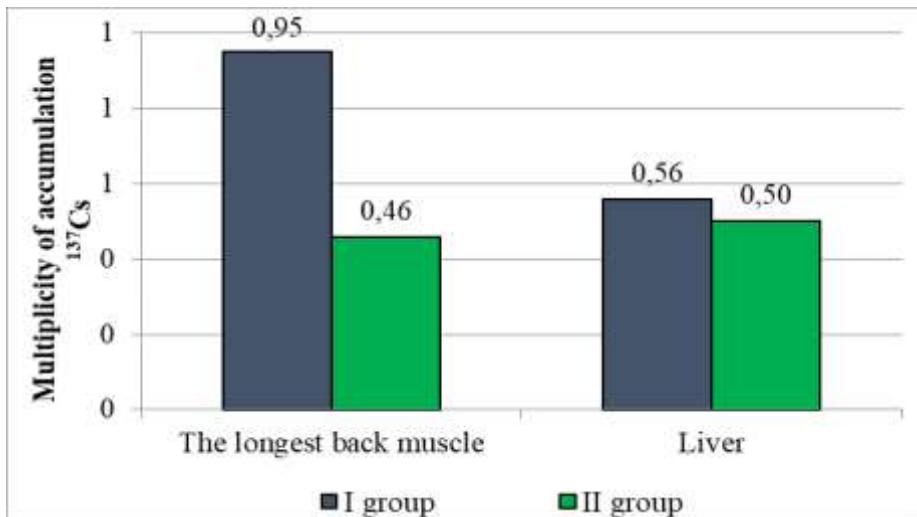


Fig. 1. Multiplicity of ^{137}Cs accumulation in the longest back muscle and liver of experimental pigs

The multiplicity of accumulation of ^{137}Cs in the liver of experimental animals varied between 0.50-0.56 and was 12.0% higher in piglets of the control group (I) compared to the II (experimental) group.

Taking into account the above, it can be asserted that the replacement of 60% of wheat grain and 10% (by mass) of sunflower and lupine cake with the appropriate amount of corn grain and GM soybeans for fattening young pigs in the Polissia zone of Ukraine leads to a reliable decrease in the specific activity of ^{137}Cs in the longest back muscle and insignificant in the liver.

According to the researchers' reports (Wang Y. et al, 2018), heavy metals of high toxicity Pb, Cd, Hg, As, Se, F, Zn pose a special danger to farm animals and humans. Moreover, according to WHO experts and other international organizations, one of the global and dangerous environmental pollutants is Pb. This metal has sufficiently large volumes of production and a wide scope of application, which causes its arrival and distribution in various objects of the surrounding natural environment. The ability to accumulate in organs and tissues, high biological activity of Pb pose a real threat to human and animal health. At its blood concentration of 200-400 $\mu\text{g/l}$, people may develop signs of poisoning (Yabe J. et al., 2015).

Experimental studies showed that a significant amount of Pb entered the body of experimental pigs with feed rations, the daily consumption of which by young pigs ranged from 2.464 to 3.641 mg and was 47.8% higher in the I (control) group than in II (experimental) group (Table 3).

Based on the results of the research, it was established that in the longest back muscle of pigs of both experimental groups, the accumulation of Pb was significantly lower than the MPC (0.50 mg/kg) and varied within 0.170-0.206 mg/kg. However, as a result of the introduction of 60% of corn grain and 10% (by mass) of GM soybeans into the grain mixture, the concentration of Pb in the muscle tissue of animals of II group decreased by 0.036 mg/kg, or by 17.5% ($P < 0.95$) compared to the corresponding indicator for feeding young animals with grain-carrying mixture № 1.

The opposite pattern was observed in the accumulation of Pb in the liver of experimental young pigs. Thus, with the introduction of corn and GM soybeans into the composition of the grain mixture, the concentration of Pb in the liver of animals of the II (experimental) group compared to the I (control) group increased by 0.048 mg/kg, or



by 18.5% ($P < 0.95$). It should be emphasized that the concentration of Pb in the liver of piglets of both groups was lower than TLK by 48.7-56.7%.

Table 3

Concentration of Pb in feed rations and products (n=3; M ± m)

Groups of pigs	Concentration of Pb			
	average daily ration, mg	production, mg/kg	± to control	
			mg/kg	%
The longest back muscle				
I - control	3.641	0.206 ± 0.018	-	-
II - experimental	2.464	0.170 ± 0.014	-0.036	-17.5
TLK	-	0.50	-	-
Liver				
I - control	3.641	0.260 ± 0.007	-	-
II - experimental	2.464	0.308 ± 0.029	+0.048	+18.5
TLK	-	0.60	-	-

As for the transition of Pb from ration fodder to the longest back muscle and liver of young pigs, it should be noted that this indicator was higher in animals of II (experimental) group by 1.24% and 5.36% abs. than in I (control) group (Fig. 2).

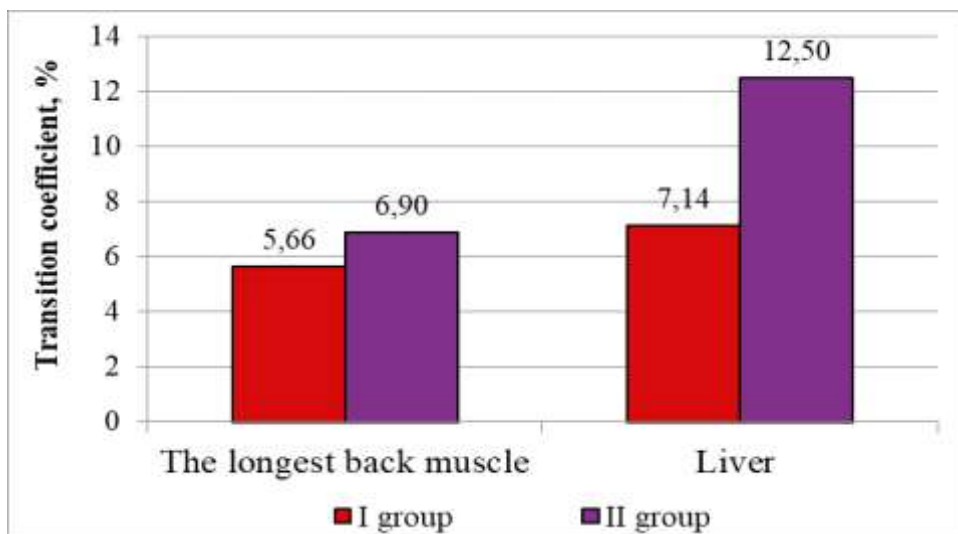


Fig. 2. Coefficients of Pb transition into muscle tissue and liver of pigs

Cadmium is one of the most toxic heavy metals, it belongs to the second class of danger as highly dangerous substances (Lavryshyn Y. et al., 2018). Like most other heavy metals, Cd has a clear tendency to accumulate in the body: its half-life is 10–35 years (Lavryshyn Y. et al., 2019). Cadmium has a harmful effect on the vital systems of human and animal bodies, causing pathological changes in tissues and organs (kidneys, lungs, bone tissue, organs of the reproductive and endocrine systems), suppressing the process of erythropoiesis (Peng L. et al., 2015). Cadmium and its compounds are immunotoxicants that lead to disturbances in the functioning of the body's immune system, reduce resistance to infections, and contribute to the formation of allergic, autoimmune, and oncological pathologies (Ostapyuk A.Y., GutyjB.V., 2020). The feature of the biological action of Cd is its ability to negatively affect the health of animals with



long-term exposure to low levels of pollution due to a high coefficient of biological accumulation (up to 40 years) (Lavryshyn Y., Gutyj B., 2019).

The content of Cd, which entered the body of experimental young pigs of the large white breed after being fed with different versions of grain mixtures, was significantly lower than Pb, which was 0.293-0.345 mg/day (Table 4).

Table 4

Concentration of Cd in feed rations and slaughter products of pigs (n=3; M ± m)

Groups of pigs	Concentration of Cd			
	average daily ration, mg	production, mg/kg	± to control	
			mg/kg	%
The longest back muscle				
I - control	0.345	0.072 ± 0.003	-	-
II - experimental	0.293	0.070 ± 0.004	-0.002	-2.8
TLK	-	0.05	-	-
Liver				
I - control	0.345	0.118 ± 0.009	-	-
II - experimental	0.293	0.098 ± 0.007	+0.020	-16.9
TLK	-	0.30	-	-

According to the research results, it can be stated that the concentration of Cd in the muscle tissue of experimental pigs varied in a small range of values 0.070 – 0.072 mg/kg. This indicator in animals of I and II groups was higher than the maximum permissible concentration by 1.44 and 1.40 times, respectively. The improbable intergroup difference in the content of Cd in the longest back muscle was established depending on the feeding of fattening pigs in rations of different composition of grain mixtures: in the meat of young animals of II (experimental) group relative to the I (control) group, this indicator was lower by 2.8% (P<0.95).

A much larger amount of Cd accumulates in the liver of experimental animals, 0.098-0.118 mg/kg, while this indicator did not exceed TLK (0.30 mg/kg). Instead, the smallest amount of Cd was contained in the liver of piglets of II group (0.098 mg/kg), which were fed with grain mixture № 2.

The transition coefficients of Cd in pork (longest muscle) and liver were quite high, 20.87-23.89 and 33.45-34.20%, respectively (Fig. 3). When feeding young pigs with grain mixture № 2, the coefficient of Cd transition into the muscle tissue of animals of II group compared to I group increases by 3.02% abs., while using different variants of grain mixtures, the transition of Cd into the liver of young pigs of both groups did not differ significantly (33.45-34.20%).

The average daily intake of trace element Cu in the body of fattening animals with fodder rations did not differ significantly between the experimental groups and was in I group 27.2 mg/day, in II group 27.9 mg/day (Table 5). The concentration of Cu in the longest back muscle of young pigs of both groups was low (0.91-0.95 mg/kg) and did not exceed TLK (5.0 mg/kg). The use of grain mixtures of different composition for fattening pigs did not have a significant effect on the content of this element in meat, however, it was 4.2% lower in animals of II group than in the analogues of I group.

The main depot of Cu in the body of animals is the liver, the content of the element in which was 10.0-22.2 times higher than in the longest back muscle. When using the proposed variants of grain mixtures of corn and GM soybeans, the concentration of Cu in the liver relative to the control decreased by 10.70 mg/kg, or by 52.9% for a prob-



able difference ($P>0.95$). At the same time, in young pigs of I (control) group, the content of Cu in the liver was at the level of TLK (20.21 mg/kg).

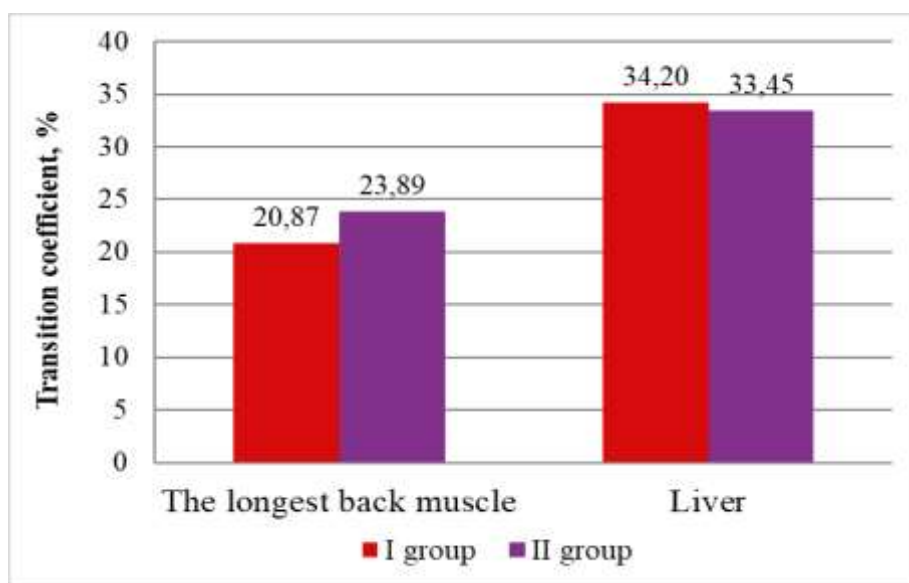


Fig. 3. Coefficients of Cd transition into muscle tissue and liver of pigs

Table 5

Concentration of Cu in feed rations and products (n=3; M ± m)

Groups of pigs	Concentration of Cu			
	average dai-ly ration, mg	production, mg/kg	average daily ration, mg	
			mg/kg	%
The longest back muscle				
I - control	27.2	0.95 ± 0.06	-	-
II - experimental	27.9	0.91 ± 0.03	-0.04	-4.2
TLK	-	5.0	-	-
Liver				
I - control	27,2	20.21 ± 2.46	-	-
II - experimental	27,9	9.51 ± 0.62*	-10.70	-52.9
TLK	-	20.0	-	-

Note. * - $P>0.95$

The transition coefficients of Cu from the forages of the rations to the liver of animals were high, 34.09-74.30%, compared to 3.26-3.49% in the longest back muscle (Fig. 4). The positive trend was noted as with the introduction of corn and GM soybeans into the fodder grain mixture, the accumulation of Cu in both the longest back muscle and the liver of young pigs of II (experimental) group relative to the control decreased by 0.23% and 40.21% abs., respectively.

On the basis of research conducted on the fattening of young pigs in III zone of radioactive contamination, certain regularities of the transformation of heavy metals into the products of animal slaughter have been revealed. Thus, according to our data, the transition coefficients of individual metals were (%):

- in the longest back muscle: Cd-20.87-23.89>Pb-5.66-6.90>Cu-3.26-3.49;
- in the liver: Cu – 34.09-74.30 > Cd – 33.45-34.20 > Pb – 7.14-12.50.



This makes it possible to state that among the studied metals, Cd is characterized by significant accumulation properties in muscle tissue, and Cu in the liver. The transition coefficients of Cd into pig slaughter products were 2.7-4.8 times higher compared to Pb.

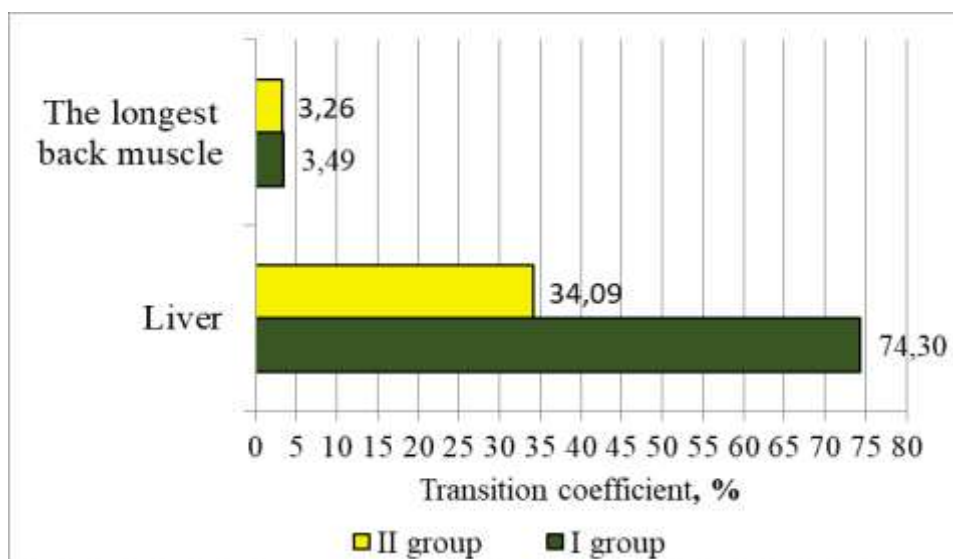


Fig. 4. Transition coefficients of Cu into products

Therefore, the use of grain mixture No. 2 (corn + triticale + GM soy + PMVA) for fattening young pigs in the accident zone at the Chernobyl NPP had a positive effect on the ecological quality of pig farming products, reducing the specific activity of ^{137}Cs and the concentration of heavy metals, in particular Pb, Cd and Cu.

Discussion. The replacement of 60% (by mass) of wheat grain, 10% of cake and lupine in the composition of the grain mixture with the appropriate amount of corn chaff and GM soybeans for fattening young pigs in III zone of radioactive contamination had a positive effect on the ecological quality of pork, reducing in the longest back muscle and the liver, the specific activity of ^{137}Cs and the concentration of heavy metals, in particular Cd, Pb and Cu. This can be explained by a slightly better provision of protein in the rations of young pigs of the research group and its better amino acid composition. Thus, the ratio of amino acids to crude protein in the rations of animals of groups I and II was (%): lysine – 4.26 and 5.33, methionine + cystine – 3.07 and 3.13, threonine – 3.07 and 4.80, respectively. Therefore, the content of essential amino acids in the feed of the ration can serve as one of the indicators of the overall protein quality.

According to research by both domestic and foreign authors (Mamenko O.M., Portiannik S.V., 2021; Savchuk I.M. et al., 2021; Chalabis-Mazurek A. et al., 2021), the transition of radionuclides and heavy metals from feed to products depends on ecological and technological conditions of production, type and degree of digestibility of feed, age and physiological state of animals, as well as to a large extent from the level and full value of feeding, balance of rations in terms of substances that have radio-protective properties. These substances increase the body's resistance to radiation, accelerate the removal of radionuclides and heavy metals, and reduce their content in products. Such substances include many amino acids (especially sulphur-containing ones), fibre, minerals, vitamins, especially A, E, groups B, C. (Hashemi S., 2018; Moharrery et al., 2015).

In addition, the selection of the optimal type of animal feed contributes to a significantly lower transition of radionuclides and heavy metals into livestock products, which is confirmed by studies conducted on dairy cows, young cattle and pigs



(O.M. Mamenko, S.V. Portyanik, 2019; Savchuk I. et al., 2021; Zhukorskyi O.M. et al., 2018).

Conclusions.

1. When various high-protein feeds were used to optimize the protein nutrition of young pigs, the specific activity of ^{137}Cs in the longest back muscle and liver of the experimental animals varied by group within the range of 3.7-10.3 Bq/kg and 4.0-6.0 Bq/kg, respectively, and did not exceed permissible levels (DR-2006 = 200 Bq/kg). The introduction of GM soybeans into the grain mixture, the concentration of radioisotopes in the muscle tissue of pigs of II (experimental) group relative to the control decreased by 6.6 Bq/kg, or by 64.1% with a statistically significant difference ($P > 0.95$). Therefore, the multiplicity of accumulation of ^{137}Cs in the longest back muscle of piglets was 0.46-0.95 and was 2.1 times higher in young pigs that received grain mixture No. 1 without GM soy compared to the use of grain mixture № 2.

2. The concentration of Pb and Cu in the slaughter products of experimental animals was significantly lower than TLK, while the level of contamination of the longest back muscle of pigs Cd exceeded the regulatory requirements by 1.40-1.44 times. The introduction of 60% (by mass) of corn grain and 10% of GM soybeans into the grain mixture instead of a similar amount of wheat grain, lupine and sunflower cake for feeding animals in III zone of radioactive contamination contributes to a significantly lower accumulation of heavy metals in muscle tissue and liver (excluding the content of Pb in the liver): Pb – by 17.5%, Cd – by 2.8 and 16.9%, Cu – by 4.2 and 52.9%, respectively. Thus, the coefficients of transition of heavy metals into the products of pigs depended on their consumption with fodder in the rations with a higher content of Pb and Cd in the rations, their transition coefficients into the longest back muscle and liver decrease.

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