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ORIGINAL ARTICLE

Specific activity of Sr-90 and Cs-137 in rabbits of various genotypes

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Numerous researches conducted by scientists in many countries in the world still do not give a complete picture of the specific activity and aftereffect of Sr-90 and Cs-137 on the animal organisms. The specific activity of radionuclides in meat products, muscles, and bones of rabbits is also of great importance when creating new genotypes. We conducted research in individual muscle groups and rabbit bones to study the relationship between growth rate, origin and specific activity of Sr-90 and Cs-137 radionuclides in dynamics over three stages of control cultivation (2-, 3- and 4th month). During the whole period of young rabbits growing, we determined the intensity of growth, fattening productivity by post-weighing on electronic weight and developed indices. These indicators were higher in the crossbreeds of rabbits of the new type of chinchilla being created (NTSH) compared to the peers of the local chinchilla (LS). Thus, during the growing period the weight gain of one head of this genotype (NTSH) was greater by 170 g than the peers (LS). We registered that the specific activity of Sr-90 and Cs-137 in the muscles and bones of young rabbits of the investigated genotypes, providing intensive cultivation, changes with age with success. The specific activity of Sr-90 decreases in the muscles of young rabbits during the fattening period (60-120 days) from 0.032 to 0.018 Bq/kg, and in the bones increases from 0.348 to 0.584 Bq/kg. We proved that the specific activity of Cs-137 on the contrary in muscles with age increases from 0.63 to 0.732 Bq/kg, and in bones decreases from 7.13 to 5.936 Bq/kg. We also found out that the specific activity of Sr-90 in the muscles is lower by 0.011–0.02 Bq/kg (37.9–45.5%), and in the bones by 0.44 Bq/kg (55.9%) in young rabbits of newly formed chinchilla (NTSH) under intensive cultivation compared to young rabbits of local chinchilla (LS). The specific activity of Cs-137 in the muscles of the newly formed three-breed chinchilla was also lower by 0.18–0.21 Bq/kg (22.3–22.4%), and in the bones by 1.08 – 1.22 Bq/kg (13.2–18.8%). We suggested that the specific activity of Sr-90 and Cs-137 radionuclides in carcasses of young rabbits under the conditions of natural radioactive background of the Carpathian region is insignificant and depends on the genetic characteristics of the animals and to a greater extent on the complete feeding.

Key words: Rabbits; Compound feed; Genotype; Radionuclides; Sr–90; Cs–137; Resorption; Natural radioactive background; Regularity

Introduction

The problem of producing environmentally safe livestock products after radionuclide contamination of most of the territory of Ukraine is still very important. The radiation threat from products produced on contaminated lands will remain for many years (Harkness & Wagner, 1995; Luchyn, 2009; Piskovyi, 2010). More than 30 years have passed since the accident at the Chernobyl nuclear power station. However, the specific activity of Cs-137 in feed grown in the farms of the Ivano-Frankivsk region ranges from 2.2 to 20.43 Bq/kg, and in some samples this indices is even higher. The specific activity of Cs–137 in soils is in the range 29.4–242.3 Bq/kg, Sr–90 – from 1.66–13.16 Bq/kg. After the Chernobyl accident, among the large number of artificially radioactive nuclides, the mixed $\beta - \gamma$ – Cs-137 radiator is one of the longest existing (Mamenko, 2007). The place of its greatest localization in the organism of animals is muscle tissue (Trofimova, 2000; Zalipukhin, 2010; Darmohray et al., 2017; Bashchenko et al., 2019). Due to the large scale of man-made pollution of the environment, radionuclides are included in the international and domestic lists of pollutants to be controlled (Paul-Murphy, 2007; Piskovyi, 2009).

Upon receipt in the organism of animals, the deposition of radionuclides is determined by the solubility of the substance in the content of different parts of the digestive system, chemical properties of nuclide, species (genetic), age and physiological characteristics of the organism, the balance of basic nutrients in the ration and other factors (Darmohrai & Luchyn, 2005; Darmohrai & Luchyn, 2011; Darmograj & Luchin, 2016; Darmohray et al., 2017).

The chemical composition of the mineral part of the feed, i.e. the presence of isotopic or non-isotopic carriers, has a great influence on the level of absorption and deposition of radionuclides. For example, calcium-rich feed decreases Sr-90 resorption and its subsequent deposition in the skeleton, and calcium-deficient feed, on the contrary, increases intestinal absorption of strontium-90 (Malynovskyi & Romanchuk, 2001). Optimization of carbohydrate nutrition of fattening steers has a positive influence on their gains, reducing the concentration of Cs-137 in the meat and liver of experimental steers respectively by 5.3–21.7% and 15.4–19.6% (Savchenko & Savchuk, 1998). With the constant intake of cesium – 137 into the geese organism, the average rate of accumulation per day in the muscles was: at 2 months – 16; at 3 months – 15.6; at 4 months – 5.3 Bq/day (Malynovskyi & Romanchuk, 2001).

The researches by L. N Burykina and E. I. Yartseva on two groups of dogs (Luchyn, 2009) indicate that global Sr-90, which comes into the organism of productive animals in ultra-small numbers, is deposited faster than with one-time feeding of the indicator dose. The excretion of radionuclides in adults is much faster than in young animals. The activity level of Cs-137 in meat is related to the

degree of contamination of natural land by radioactive fall-out (Piskovyi, 2009). So, these substances fall more in coastal and mountainous areas, where the meat of productive animals is more contaminated with this radionuclide (Vokken, 1967).
The role of the natural radioactive background in the processes of activities is closely intertwined with the general problem of the action of small doses of ionizing radiation on the organism and still remains one of the little studied issues of radiobiology. Based on the use of ecological mechanisms of population transformation, it is theoretically possible to consciously control the evolutionary process directly in nature, to create new forms of animals, more efficient use of environmental resources, increase the efficiency of energy and geochemical work of biogeocenoses (Ivashura & Tkachova, 2004). Artificial selection, based not only on the functional but also on the energetic evaluation of the adaptive reactions of animals, can lead to the creation of new species of animals with specified properties (Luchyn et al., 2015; Luchyn & Darmohrai, 2016; Bashchenko et al., 2019).
Therefore, research on the dynamics of transformation, the specific activity of radionuclides in the organism, the tissues of rabbits of different genotypes (Maertes et al., 2004; Darmohray et al., 2019) are of great importance. The question of the specific activity of radionuclides in rabbit carcasses in the creation of new genotypes remains important and unexplored.
The purpose of the research was to determine and compare the dynamics of the specific activity of Sr-90 and Cs-137 radionuclides in the muscles and bones of young rabbits of different origin at three stages of control cultivation (2, 3 and 4 months of age) in intensive production.

Material and Methods

The search of fattening and slaughter indices of young rabbits was carried out in the farm "Elite" of the Kolomyja district, Ivano-Frankivsk region (Luchyn, 2009), and radiological investigations in the livestock laboratory of the Kolomyja Experimental Station. The material used for the work was genotype rabbits: local chinchilla – *(LS)* and three – breed flanders, chinchilla and white giant) – *(NTSH).* To achieve this goal, according to the principle of analogues, was selected and formed 2 groups of rabbits of 30 heads in each, the age of rabbits when setting on research 45–50 days. The rabbits of the two experimental groups were fed a mixed ration which for nutritional purposes consisted of 70% concentrated feed (granular concentrate) and 30% green mass of oats. Feeding rates and establishing the need for nutrients for experimental animals were performed according to the rabbit nutrition requirements approved by the VIII International Rabbit Congress (EGRAN tables, 2004) (Maertes et al., 2004).
Specific activity of Cs-137 in feed was determined by gamma-ray spectrometry using the RIG-01γ radiometer, specific activity of Sr-90 in feed was determined by radiochemical method (Metodicheskie ukazanija…, 1985). The determination of specific activity of both Cs-137 and Sr-90 in carcasses of young rabbits of different age was performed according to the methods of the Central Institute of Agrochemical Services for Agriculture (CIASA) (Metodicheskie ukazanija…, 1985), by (oxalate method) complete removal of the radionuclide in isotope-pure form from the mass of meat and bone samples taken for analysis with a final measurement on a SSB device – 1500.
During the experiment (from 45 to 120 days) in young rabbits was studied the intensity of growth and costs, conversion of feed per unit of production. At 2, 3 and 4 months of age, rabbits were slaughtered, five heads of each genotype, and the specific activity of radionuclides (Cs-137, Sr-90) in the muscles and bones was determined (Instruktivno-metodicheskie ukazanija…, 1970). All weightings were performed on electronic scales with an accuracy of 1 gram. In order to protect the products of animal origin and food security of people in general, the Ministry of Health of Ukraine developed and issued the order of 03.05.2006 No. 256, on the level of permissible specific activity of radionuclides in food and drinking water (Table 1).

Table 1. Values of allowable levels of specific activity of radionuclides Cs-137 and Sr-90 in food and drinking water.

Product name	**DR-2006 Cs-137 Bq/kg**	**DR-2006 Sr-90 Bq/kg**
Meat of slaughtered animals, poultry (fresh, chilled, frozen) boneless for industrial processing, meat, food by-products (including gut- adobe, edible blood) of slaughtered animals and poultry fresh, frozen, in various ways processing; products of their processing, incl. semi-finished products, finished products, sausages, canned meat and meat-vegetable	200	20
Meat of wild animals and poultry	400	40
Fat of slaughtered animals (including speck) and poultry, products of its processing	100	30
The meat of slaughtered animals, poultry, dried and the products of its processing	400	40
Bones of animals and poultry of all kinds	50	200

In all experimental groups of rabbits' feeding of the granulated compound feed and green mass was enough, taking into account eating. Access to water was safe and regular. Rabbits were kept in cages with premises. Biometric processing of digital data was performed using MS Excel software using built-in statistical functions. The values were considered significant at $P<0.05$, $P<0.01$, and $P<0.001$ compared to control.

Results

In the feed analysis, the specific activity of Sr-90 and Cs-137 in the compound feed and the green masses of the vetch-oat mixture were determined (Table 2). It was set up that the specific activity of radionuclides in feed was within acceptable limits and was, in the compound feed Sr-90 – 0.56 Bq/kg, Cs-137 – 5.13 Bq/kg, in the green mass of the vetch-oat mixture, respectively, Sr-90 – 4.4 Bq/kg and Cs-137 – 0.6 Bq/kg. For objective information on the intake of radionuclides from forages, the activity of Sr-90 and Cs-137 in a single forage unit was determined in the rabbit organism based on the structure of the ration, forage consumption and feed costs per kg of growth over growing periods.

Table 2. The content of radionuclides in feed and their intake with the ration of rabbits, (n = 5).

Forage	Radionuclides, Bq/kg			
	^{90}Sr		^{137}Cs	
Compound feed (ABO MIX recipe)	0.56 ± 0.051		5.13 ± 0.293	
Green weight Viko-oat mixture	4.4 ± 0.324		0.6 ± 0.058	
In 1 kg units. ration	38.68		20.84	
Growing period, days	**The genotype of rabbits**			
	NTSH	***LS***	***NTSH***	***LS***
46–60	69.68	75.8	37.54	40.84
61–90	172.38	164.67	92.88	88.72
91–120	231.8	216.0	124.89	116.38
46–120	473.86	456.47	255.31	245.94

In the course of the research, we found a slightly higher activity of radionuclide uptake into the organism of fodder in the NTSH young stock, which is associated with higher productivity and higher feed intake. During the whole period of cultivation, the intake of Sr-90 and Cs-137 from the ration was slightly higher in animals of the genotype (NTSH), the newly created three- breed chinchilla (Sr-90 – 473.86 Bq/kg; Cs-137 – 255.31 Bq/kg).

It was found that the rabbits of the genotype of the newly formed three-breed chinchilla have accumulated less specific radionuclide activity in the muscles and bones (Table 3). Thus, at the age of 2 months, the bones of the newly formed three-breed chinchilla contained 0.442 Bq/kg less Sr-90 compared to the local chinchilla (P<0.001).

At 3 months of age, these mixtures contained significantly less Sr-90 in the muscles – by 0.02 Bq/kg compared to the local chinchilla (P<0.001). The same picture pattern was observed at 4 months of age. The specific activity of Sr-90 in the muscle of the mixes was 0.011 Bq/kg less than the local chinchilla (P<0.001).

As for Cs-137, in the organism of the newly created three-breed chinchilla its activity grew less. Thus, at 2 months of age Cs-137 was less in muscles by 0.181 Bq/kg (P<0.05) and in bones by 1.08 Bq/kg (P<0.05) compared to local chinchilla. In the 3- and 4-month of age the specific activity in the bones of the newly formed three-breed chinchilla Cs-137 was also lower by 1.22 Bq/kg (P<0.001) and by 1.17 Bq/kg (P<0.01) compared to the local chinchilla .

Table 3. Dynamics of specific activity of Sr-90 and Cs-137 in the muscles and bones of young rabbits, (n = 5).

Genotype	Radionuclides, Bq/kg			
	^{90}Sr		^{137}Cs	
	Muscles	**Bones**	**Muscles**	**Bones**
		2 months		
NTSH	0.032 ± 0.003	0.348 ± 0.022***	0.63 ± 0.038*	7.13 ± 0.318*
LS	0.086 ± 0.004	0.79 ± 0.061	0.811 ± 0.056	8.21 ± 0.277
		3 months		
NTSH	0.024 ± 0.002***	0.346 ± 0.017	0.468 ± 0.023	5.35 ± 0.188***
LS	0.044 ± 0.004	0.575 ± 0.033	0.777 ± 0.045	6.57 ± 0.207
		4 months		
NTSH	0.018 ± 0.002***	0.584 ± 0.009	0.732 ± 0.026***	5.936 ± 0.132**
LS	0.029 ± 0.002	0.826 ± 0.012	0.939 ± 0.030	7.106 ± 0.116

*P<0.05, **P<0.01, ***P<0.001 compared to the control group.

The data in the table indicate the sequence of changes in the specific activity of Sr-90 and Cs-137 in the muscles and bones of young rabbits during the experiment. The increase in the specific activity of these radionuclides in the rabbit muscles was uneven. Thus, the specific activity of Sr-90 decreases from 0.032–0.086 Bq/kg at 2 months of age to 0.018–0.029 Bq/kg at 4 months, which is characteristic of Sr-90 because it is an isomorphic carrier for stable calcium. The lower the concentration of the carrier, the greater the sorption of the radioactive substance by the organism. Slightly higher activity in Sr-90 muscles is observed in rabbits of origin of the local chinchilla: by 0.005–0.06%, which is probably due to the genotype and poorer yield of feed gain, compared to the rabbits of the newly created three-breed chinchilla (NTSH).

In this case, there is an inverse tendency of Sr-90 activity in the bones. When slaughtering rabbits at 2 months of age, its specific activity was 0.348–0.79 Bq/kg, which is 0.3–0.69% more than at slaughter at 3 months of age. Obviously, some earnings into the Sr-90 rabbit organism were occurred during the prenatal and lactation periods. At 4 months, Sr-90 activity in the rabbit bones of the newly formed local chinchilla increased to 0.584 Bq/kg and in the local chinchilla to 0.826 Bq/kg. The intensity of the specific activity of this radionuclide is higher and in the bones of rabbits of local chinchilla genotype, compared to the three-breed peers. During the whole experiment in two groups of rabbits, the specific activity of Sr-90 in the muscles was decreased dynamically, instead was increasing in the bones.

A similar tendency in the specific activity of Cs-137 was observed in carcasses of growing young rabbits of different origin and content in the muscles and bones at 2 months of age, relative to rabbits 3 and 4 months of age. There is also a certain pattern of activity of this radionuclide for two groups of rabbits in the process of cultivation: the accumulation of Cs-137 in the bones increases slowly from 5.356 to 5.936 Bq/kg; from 6.57 to 7.106 Bq/kg, and in the muscles – more intensively from 0.468 to 0.732 Bq/kg; from 0.777 to 0.939 Bq/kg. This is due to the fact that potassium is an isomorphic carrier for cesium, which is in the muscles, and its presence depends on the concentration level Cs-137.

The concentration of Sr-90 and Cs-137 radionuclides in carcasses of rabbits under the conditions of natural radioactive background of the Carpathian region is negligible and depends on the genetic characteristics of the animals and to a greater extent on the completeness of feeding.

In the process of research the productivity of two genotypes and the specific activity of Sr-90 and Cs-137 is also determined of young rabbits when they were fed with feed under conditions of a constant radiological background and in carcasses of rabbits different in age. It was found that the accumulation of radionuclides in the bones of strontium is at the level of 0.348–0.826 Bq/kg, cesium – 5.356–7.106 Bq/kg, and in the muscles 0.086–0.018 Bq/kg and 0.63–0.811 Bq/kg respectively, the specific activity of radionuclides in rabbit carcasses is negligible and does not impair the quality of meat (Table 3).

The radionuclide activity in the meat and bones of young rabbits of the two experimental groups at different slaughter periods was significantly lower than the admissible levels of specific activity of Cs-137 and Sr-90 radionuclides.

Discussion

The problem of producing environmentally permissible livestock products after the contamination of radionuclides by most of the territory of Ukraine remains an important and urgent one. The specific activity of Cs-137 in soils is in the range 29.4–242.3 Bq/kg, Sr-90 from 1.66–13.16 Bq/kg. (Mamenko, 2007). Deposition of radionuclides upon earnings into the organism of animals is determined by the assimilation of feed in different parts of the digestive system, the chemical properties of the nuclide, species (genetic), age and physiological features of the organism, the balance of the basic elements of nutrition in the ration and other factors (Vokken, 1967; Zalipukhin, 2010). The chemical composition of the mineral component, the feed particles, that is, the presence of isotopic or non-isotopic carriers, has a great influence on the level of assimilation and deposition of radionuclides (Zasiekin et al., 2008). Calcium-rich feed decreases Sr-90 resorption and its subsequent deposition in the skeleton and calcium-deficient feed, in contrast, increases intestinal resorption of Sr-90. For cesium, isomorphic potassium is carrier, which is found in the muscles, and its presence depends on the concentration level Cs-137 (Piskovyi, 2010). The specific activity of radionuclides in the feeds of the experimental rabbit groups was found to be: Sr-90 – 0.56 Bq/g, Cs-137 – 5.13 Bq/kg.

The question of the accumulation of radionuclides in rabbit carcasses in the creation of new genotypes remains important and unexplored (Luchyn, 2009). In the course of the research, we found a slightly higher intake of radionuclides with feed from the local rabbit feed (NTSH), which is associated with higher productivity and greater feed intake. We determined that the specific activity of Sr-90 and Cs-137 in the muscles and bones of young rabbits of this genotype, under conditions of intensive cultivation, changes with age with success. The specific activity of Sr-90 is decreased in the muscles of young rabbits during the fattening period (60–120 days) from 0.032 to 0.018 Bq/kg ($P<0.001$), and in the bones is increasing from 0.348 to 0.584 Bq/kg ($P<0.001$). The specific activity of Cs-137, on the contrary, increases with age from 0.63 to 0.732 Bq/kg ($P<0.001$) and decreases from 7.13 to 5.936 Bq/kg ($P<0.01$) in bones.

Conclusion

We found that in the newly created chinchillas, under the conditions of intensive cultivation, the specific activity of Sr-90 in the muscles was reduced by 0.011–0.02 Bq/kg or by 37.9–45.5% ($P<0.001$), and in the bones, 0.44 Bq/kg or 55.9% ($P<0.001$) of young rabbits of local chinchillas were sewed (LS). The specific activity of Cs-137 in the muscles of the newly formed three-breed chinchilla decreased by 0.18–0.21 Bq/kg or by 22.3–22.4% ($P<0.001$), and in the bones by 1.08–1.22 Bq/kg or 13.2–18.8% ($P<0.001$). This fact is probably due to the origin and worse payback of feed gain compared to the three breeding local rabbits (NTSH). The concentration of Sr-90 and Cs-137 radionuclides in carcasses of rabbits in the conditions of the natural radioactive background of the Carpathian region is negligible and depends on the genetic characteristics of the animals and to a greater extent on the completeness of feeding. In our opinion, we need to conduct comprehensive research involving broader current methods and techniques and scientific laboratories to address this issue.

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