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ORIGINAL ARTICLE

Trace elements transformation in young rabbit muscles

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According to scientific publications, transformation of nutrients in the rabbit feed should be studied with regard to rabbit nutritional specifics that is caused by differences of alimentary canal of the species, involving microorganism role in the digestive process. In the experiment, The research considered the transformation of essential micronutrients of feed (Zn, Cu, and Mn) and their concentration in muscle carcasses of rabbits of differentl age and origine, in industrial rabbit production in Prykarpatyia. Feeding norms and nutrient requirements for experimental animals were performed according to rabbit nutrition requirements approved by the VIII International Rabbit Congress (EGRAN tables, 2004). It has been found out that supplying rabbits of different genotypes with the same nutrition affect the retention of studied micronutrients in certain muscles carcasses differently. The experiment demonstrated that the longest back muscle of a 3-month old new hybrid rabbit (NTC) contented the highest amount of zinc and accounted 6.78 ± 0.118 mg kg^{-1} which was by 1.43 mg kg^{-1} ($p<0.001$) more than in the rabbits of the local chinchilla (second group). It is proved that the greatest amount of cuprum was concentrated in the hip carcasses of rabbits of the first group (NTC). This rabbit genotype (first group) dominated over the local breed (the second group) regarding this indicator, when the animals were 2 and 3 months old, by 0.15 and 0.49 mg kg^{-1} respectively ($p<0.01$). The content of manganese in the muscles of the hips was also higher in the newly-selected three-breed during all the farming period. Thus, at the age of 2 months, rabbits of the first group outweighed their peers in the second group by 6.52 mg kg^{-1} ($p<0.05$), at the age of 3 months – by 1.57 mg kg^{-1} ($p<0.01$) and at the age of 4 months – by 0.89 mg kg^{-1} ($p<0.01$). The three-breed rabbit genotype of of the first group was dominated by pure-breed analogues of the second group in terms of weight gain and feed conversion by 7.5 and 3.4% respectively. Due to better transformation of these trace elements, in the body of intensively growing rabbits, the environment is less polluted. The highest concentration of these trace elements was found in the rabbit muscles of both groups in the 3rd month of life. The highest content of the micronutrients studied was observed in the longest and suprascapular muscle of rabbits. The prospects of further research on the study of the transformation of other heavy minerals in industrial cultivation of rabbits has been overviewed.

Key words: Rabbits; Three-breed hybrids; Local chinchilla; Micronutrient transformation; Zink; Cuprum; Manganese; Rate of growth

Introduction

Over the last few years, much attention has been paid to the problem of environmental contamination with salt trace elements. The higher the increase of inductrial production of livestock products is, the bigger is the number of harmful elements which are included in the international and domestic lists of pollutants and are subject to control (Kabata-Pendias, 2004; Zhuang & Gao, 2014; Bai et al., 2015; Darmohray, 2016; Gutyj et al., 2019; Sobolev et al., 2019; Kovalchuk et al., 2019).

When administered to the body with feed, heavy metals are absorbed into the bloodstream in the gastrointestinal tract. In a very short time they are excreted from the blood with urine, sweat, feces, and milk. Some of the heavy metals are deposited (transformed) in the tissues, and then re-enter the bloodstream and are excreted from the body, but more slowly than accumulated (Mamenko et al., 1998; Gutyj et al., 2017).

Today, heavy metals are excreted from the body through synthetic complexes and chelates, but these drugs cause side effects in the body, in particular, the depletion of the body to trace elements (Kravtsiv et al., 2005). The main conditions for maximum production of livestock products, especially in intensive production technologies (Luchin et al., 2015), are the qualitative composition of the diet (Darmohray & Luchin, 2011; Darmohray & Luchin, 2016; Darmohray et al., 2017), the content of the required mineral substances (Luchin, 2009), taking into account the genotype, the direction of animal productivity and endogenous load of the organism with xenobiotics and contaminants (Mamenko et al., 1998; Darmohray & Luchin, 2005).

The lack essential micronutrients in the feed and water in the western region of Ukraine leads to animal adaptation to such a trace element background, but their productivity is reduced, and some animals demonstrate symptoms of microelementosis (Kravtsiv et al., 2005; Luchin & Darmohray, 2016). Thus, changes in the ecological structure directed in this field can affect the productivity of new populations with a given genetic resource in short time. Among change factors we can observe: indiscriminate elimination at different stages of a population's life cycle, age selection, change in the spatial structure of the population, and the complex of the factors mentioned above. 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 that use environment resources more efficiently, increase the efficiency of energy and geochemical work of biogeocenoses (Sedilo et al., 2018).

It is worth mentioning that the issue of trace element transformation in the rabbit body in conditions of (industrial) intensive production of rabbits has not been studied today and, taking into account the European standards of feeding, age and origine of young rabbits in the Prykarpatyia region. Having considered all the factors, we came to a conclusion that our research is important and has freat future potential (Gutierrez et al., 2002; Mamenko, 2007; Kotelevich et al., 2008; Darmohray et al., 2015; Luchin & Darmohray, 2016; Sedilo et al., 2018; Fedak et al., 2018).

Material and Methods

The study of feeding and slaughter indices of young rabbits was carried out on the "Elite" f arm in the Kolomyia district of Ivano-Frankivsk region and the livestock laboratory of the Kolomyia research station.
The material for research consisted of such genotypes of rabbits: local chinchilla (LC) and three-breed hybrids (NTC) - (3/8 local chinchilla, 1/8 - flandr 4/8 - White Giant). For the experiment, two groups of rabbits of the respective genotypes of 30 heads each were selected and formed, the age of the rabbits at the time of testing was 35 days. All studies were performed according to the scheme of studies, which is shown in Table 1). Feed rationing and setting need norms of nutrients were conducted under rules of rabbit supply which was approved by the VIII International Congress on rabbit EGRAN tables (2004) (Maertes et al., 2004). Granular feed produced in Kolomyia feed mill (ABO mix).

Table 1. The scheme of scientific research.

Genotype	Heads	Age at slaughterhouses, months	The investigated factor		
NTC	30	2 3 4	Zn, Cu, Mn	Parts of the mascara	thigh the longest muscle of the back suprapuscular muscle
LC	30	2 3 4	Zn, Cu, Mn		

Table 2. Nutritional value of the diet.

№ p/n	Indicators	Unit measurement	Contained in the diet	№ p/n	Indicators	Unit measurement	Contained in the diet
1				16	Iodine	mg	0.5
2	Exchange energy	MJ	6.31	17	Selenium	mg	0.3
3	Dry matter	kg	0.83	18	Vitamin B1	mg	6,1
4	Crude protein	Mr	171	19	Vitamin B2	mg	2.2
5	Digestible protein	Mr	137	20	Vitamin B3	mg	21.2
6	Raw fiber	Mr	134	21	Vitamin B4	Mr	0.9
7	Raw fat	Mr	30	22	Vitamin B5	mg	81.1
8	Kitchen salt	Mr	4.0	23	Vitamin B12	ICG	10.0
9	Calcium	Mr	13.0	24	Vitamin A,	IO	10025.0
10	Phosphorus	Mr	6.0	25	Vitamin D,	IO	1838.4
11	Iron	mg	204	26	Vitamin E,	mg	47.9
12	Cuprum	mg	24	27	Lysine	Mr	10.5
13	Zinc	mg	92	28	Methionine	Mr	4,8
14	Manganese	mg	90	29	Threonine	Mr	4.9
15	Cobalt	mg	0.3	30	Tryptophan	Mr	1.9

Young rabbits (two groups) were fed a mixed diet that consisted of 70% nutrient- concentrated granulated feed (for intensive feeding of rabbits) and 30% green oat mass. We studied the intensity of growth of rabbits and the cost of feed per unit of production for the first 45-120 days. Upon reaching the 2-, 3- and 4-month age five rabbits of each genotype were slaughtered and the content of trace elements in the thigh, the longest back muscle and suprascapular muscle was investigated. All weighings were performed on electronic scales. In all feeding groups, the granulated compound feed and the green mass were consumed to a full extent. Access to water was around the clock. Indoor cellular containment was arranged.
We analyzed the feeds used for feeding the rabbits and their nutritional value (Table 2). The recipe for compound feeds for research was calculated according to established standards for intensive rabbit cultivation. Feeding norms and nutrient requirements for experimental animals were performed according to rabbit nutrition requirements approved by the VIII International Rabbit Congress (EGRAN tables, 2004). The content of trace elements (Zn, Cu, Mn; gross forms) in different age rabbits was determined by the methods of the Central Institute of Agrochemical Servicing of Agriculture (CIAOSG) by atomic absorption method on the SP-115 device (CINAO, 1989). Biometric processing digital data analysis was carried out by means of software MS Excel with the use of embedded statistical functions. *P* values with the star attached to indicate $P<0.05$, two stars to indicate $P<0.01$, and three stars were used to indicate<0.001. The data in tables presented as mean and standard deviation.

Results

According to the publications of local and foreign scientists, most of the heavy metals would belong to the elements of weak and very weak biological capture. These elements are transformed into animal bodies and their products. Even at low concentrations, heavy metals can have a strong toxic effect on a living organism through the ability to replace trace elements in reactive enzyme centers, altering their function, participating in nucleic metabolism, protein biosynthesis, catalyzing reactions beyond enzymes (Vishchur et al., 2016; Martyshuk et al., 2016; Gutyj et al., 2017). We conducted an analysis of the feeds that were used to feed the rabbits as the main source of the required minerals in the animal body (Table 3). An analysis of the material in the table indicates that the content of heavy metal compounds in the feeds under study satisfies the need in nutrints for experimental rabbits by incorporating premix feed.

Table 3. Content of trace elements under study in the feed (n=5).

Metals, mg kg^{-1}	Nutrition feed (ABO MIX recipe)	 green mass of oatmeal mixture	in 1 kg of diet
Zinc (MPC=50)	41.72 ± 2.42	0.75 ± 0.06	25.97
Copper (MPC=30)	6.50 ± 0.26	0.68 ± 0.03	4.98
Manganese (MPC=150)	26.40 ± 1.24	15.90 ± 0.45	42.14

Table 3 demonstrates the contents of the three minerals in granular feed, manufactured according to European standards for intensive farming of rabbits, as well as green mass of oat mixture, grown in the fields of research stations. The increased content of zinc, cuprum, manganese in compound feed is explained by the additional introduction of salts of these elements (through premix) into the compound feed, but this level does not exeed acceptable limits (Talanov & Khmelevsky, 1991).
Nurturing of young rabbits and growth rate is characterized by age pecularities. The dynamics of the growth rate of the experimental rabbits and feed conversion are shown in Table 4.

Table 4. Dynamics of growth rate of experimental rabbits (n=30).

Age, days	Genotype NTC	 LC
	body weight, g	
45	870 ± 1.58	721 ± 2.5
60	1426 ± 2.89	1294 ± 3.04
90	2412 ± 4.81	2137 ± 3.22
120	3292 ± 5.00	2973 ± 4.02
Growing period, days	absolute gain/daily average gain, d	
46-60	556/37.10	573/38.20
61-90	986/32.30	843/28.10
46-90	1542/34.30	1416/31.50
91-120	880/29.30	836/27.90
46-120	2422/32.30	2252/30.0
Growing period, days	feed consumption per 1 kg of body weight gain, kg	
46-60	3.24	3.42
61-90	4.52	5.05
91-120	6.81	6.68
46-120	5.06	5,24

The newly-selected three-breed chinchilla rabbits had the heaviest weight throughout the farming period in comparison with their peer local chinchilla (Table 4). At the inilial stage of farming, the average weight difference in the two groups was 149 g and, at the final stage the difference increased to 319 g. Regarding absolute growth, it was also higher in the newly-selected three-breed chinchillas, compared to their peers of the local chinchilla. So during the farming from day 61 to day 120 they ranged between 880-2422 g. The highest daily average body weight gain in both groups was observed during the period of farming from 46 to 90 days, which is normal for all animals, since with age the average daily weight gain decreases. It is worth noting that with a productivity of more than 30 g per day, young rabbits reach a maximum weight at the age of 90 days, which corresponds to the standard.
The cost of feed per unit weight gain determines the efficiency of rabbit production. It was established that during the whole period of feeding – 46-120 days, the newly-selected three-breed chinchilla consumed less feed for 1 kg gain, which accounted for 5.06 kg, whereas rabbits of local chinchilla consumed higher amount of feed – 5.24 kg.
The results determining the content of trace elements in muscle groups of young rabbits at the age of 2-, 3-, and 4 months show significant difference in the transformation of these elements depending on the age, parts of carcasses, origin, and specifics of metal (Table 5). The highest zinc content was observed in newly-selected three-breed chinchillas in the longest back muscle at the age of 3 months and was 6.78 ± 0.12 mg kg^{-1}, which is 1.43 mg kg^{-1} more than the local chinchilla ($p<0.001$). Cuprum was most concentrated in the thighs of newly-selected three-breed chinchillas. The latter also dominated over local chinchillas on this indicator at the age of 2 and 3 months by 0.15 and 0.49 mg kg^{-1} respectively ($p<0.01$).
Regarding the content of cuprum in the longest muscle of the back, the newly-selected three-breed chinchilla hybrid prevailed the local chinchillas by 0.14 mg kg^{-1} ($p<0.05$) at the age of 2 months, and, being 3- and 4-month old, the local chinchilla demonstrated higher in content of cuprum by 0.29 ($p<0.01$) and 0.2 mg kg^{-1} ($p<0.01$) respectively. The newly-selected three-breed chinchilla hybrid was also observed to have lower content of cuprum in the suprapuscular muscle – 0.65 ± 0.04 mg kg^{-1}, which is 0.1 mg kg^{-1} less than the local chinchilla.

Manganese content was higher in the the newly-selected three-breed chinchilla in the thigh muscles throughout the farming period. Thus, at the age of 2 months, they were dominated by local chinchillas by 6.52 mg kg^{-1} ($p<0.05$), at the age of 3 months – by 1.57 mg kg^{-1} ($p<0.01$) and at the age of 4 months – by 0.89 mg kg^{-1} ($p<0.01$).
However, the highest content of manganese was found in the longest muscle of the back of the newly-selected three-breed chinchilla. Thus, the three-breed chinchilla overweighed the local chinchilla in the content of manganese in this muscle throughout all the growth period: at the age of 2 months – by 1.45 mg kg^{-1} ($p<0.001$), at the age of 3 months – by 1.99 mg kg^{-1} ($p<0.001$) and at the age of 4 months – by 2.21 mg kg^{-1} ($p<0.05$).

Table 5. The content of trace elements in different parts of the carcass of young rabbits, mg kg^{-1} (n=5).

Genotype	Part of the carcass	Age, month	Zinc	Cuprum	Manganese
NTC	Thigh	2	4.28 ± 0.02	0.90 ± 0.02**	8.13 ± 0.09*
		3	6.28 ± 0.12	1.77 ± 0.12**	10.38 ± 0.21***
		4	5.07 ± 0.10	0.70 ± 0.04	7.13 ± 0.07**
	The longest muscle of the back	2	6.08 ± 0.06	1.12 ± 0.06*	10.20 ± 0.24***
		3	6,78 ± 0,12***	1.64 ± 0.08**	12.40 ± 0.25***
		4	3.55 ± 0.17	0.50 ± 0.03**	8.60 ± 0.18*
	Suprapuscular muscle	2	6.90 ± 0.09	1.50 ± 0.05	14.58 ± 0.22
		3	8.21 ± 0.32	1.78 ± 0.04	16.55 ± 0.27
		4	5.17 ± 0.12	0.65 ± 0.04*	8.62 ± 0.18**
LC	Thigh	2	3.15 ± 0.02	0.75 ± 0.03	6.52 ± 0.06
		3	6.07 ± 0.05	1.28 ± 0.02	8.81 ± 0.11
		4	3.75 ± 0.09	0.72 ± 0.04	6.24 ± 0.22
	The longest muscle of the back	2	3.75 ± 0.13	0.98 ± 0.04	8.75 ± 0.21
		3	5.35 ± 0.19	1.93 ± 0.05	10.41 ± 0.25
		4	3.65 ± 0.17	0.70 ± 0.05	6.39 ± 0.13
	Suprapuscular muscle	2	4.88 ± 0.13	0.71 ± 0.03	9.85 ± 0.16
		3	6.78 ± 0.12	1.43 ± 0.04	10.87 ± 0.17
		4	5.10 ± 0.19	0.75 ± 0.04	7.92 ± 0.16

Also, high content of manganese was observed in the suprapuscular muscle of the newly-selected three-breed chinchilla at the age of 4 months. It rated 8.62 ± 0.18 mg kg^{-1}, which is 0.7 mg kg^{-1} higher than the local chinchilla. It was found out that essential trace elemenmts such as zinc, cuprum and manganese are aggregated in muscles with some regularity. Their highest content is observed in rabbits aged 3 months, regardless of the origin and part of the carcass. High content of these elements is observed in the newly-selected three-breed chinchilla aged 2 and 3 months, namely, zinc – by 0.6-1.8 mg kg^{-1}, cuprum – by 0.15- 0.48 mg kg^{-1}, manganese – by 0.5–5.15 mg kg^{-1}. This can be explained by the higher intensity of growth and metabolic processes in the organism of young rabbits of new hybrids. We have found a pattern which means that in the muscles of four-month-old rabbits of both groups contain approximately the same concentration of the trace elements studied. The research proved the difference in the content of the three trace elements in different groups of muscles at different stages of farming time, with the highest rate observed in the second and third months of life. The highest micronutrient content is observed in the longest and suprapuscular muscles.

Discussion

Minerals play a major role in unlocking the genetic potential of highly productive rabbit genotypes under intensive (industrial) production. Experimentally, zinc, cuprum, manganese are indispensable components of many enzyme systems. They are required for the growth, development and reproduction of animals. Nowadays, there is the concept of bioavailability of micronutrients, which indicates the quantitative assimilation and use of animal body trace elements or their accumulation in organs and tissues of the animal. The bioavailability of trace elements depends on the forms and sources of their entry into the animal body and on their physiological state (Petrosjan, 2010; Richards et al., 2010; Ibatullin & Holubiev, 2017; Bomko et al., 2018). T.P. Sidorchuk et al. (2010) found out that increasing the salt concentration of trace elements in feeding Simmental calves has positive influence on the increase of protein content, fat and dry matter. Also, there was an increase in the content of trace elements of zinc, cuprum and manganese in meat. Our study was aimed at specifying of the transformation of zinc, copper and manganese in intensive farming of young rabbits under conditions of massive scale production. Three-breed (domestic) young rabbits showed higher fattening properties by 3.4-7.5% in industrial conditions, with a higher concentration of these elements by 10-25% in meat compared to the less productive genotype. This was a specific feature of the implementation of genetic potential of highly productive rabbit genotypes.

Conclusion

It was found that three-breed young rabbits (group 1) dominated over analogues of local chinchilla (group 2) by weight gain and feed conversion by 7.5 and 3.4% respectively. Consequently, higher levels of zinc, copper and manganese were observed in the carcass of the first group of rabbits. The highest content of these trace elements was present in the longest muscle of the back and the abdominal muscles of these mixtures at the age of 3 months, in which the growth rate and, accordingly, the metabolism were better. The regularity of the higher concentration of heavy metals in newly-selected three-breed chinchillas under the conditions of intensive farming has been established. The highest content of heavy metals is observed at the age of 3 months, namely, in the longest muscle of the back, a higher zinc content of 1.43 mg kg^{-1} or 26.7% ($p<0.001$), and manganese – at 1.99 mg kg^{-1} or 19.1% ($p<0.001$), in thigh – higher copper content by 0.49 mg kg^{-1} or 38.3% ($p<0.001$) and cadmium by 0.03 mg/kg or 150% ($p<0.001$), in the longest muscle, a higher lead content of 0.29 mg kg^{-1} or 76.3% ($p<0.01$) is observed.

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