Викладено результати досліджень, що пов'язані з вивченням зміни якісних показників та технологічних властивості м'яса і сала свиней за умов різного складу раціонів, а саме з додаванням Свинцю і Кадмію (сумісно та окремо) в дозі 20 гранично допустимих концентрацій. Надана оцінка ефективності захисного технологічного прийому (згодовування експериментальної рослинної добавки) при одночасному надходженні з раціоном важких металів, з метою відновлення якості продукції свинарства. Встановлено, що Свинець і Кадмій, як при сумісному так і окремому надходженні в організм молодняка свиней з кормом, мали негативний вплив на харчову та біологічну цінність свинини та її технологічні властивості. Під їх дією знижувалась калорійність м'яса, утримання в ньому білку, жиру, сухих речовин, при цьому найсуттєвіші зміни спостерігалися у тварин IV групи, де Свинець і Кадмій надходив разом. Активна кислотність м'яса та її вологоутримуюча здатність тварин всіх груп знаходились в межах норми. Однак у тварин, які отримували з раціоном підвищені дози важких металів, pH м'яса дещо змінювалось в бік нейтрального середовища (pH – 5,3–5,5, при контролі pH – 5,1), вологоутримуюча здатність м'яса дослідних тварин коливалась від 55,1 % до 56,5 % (контроль – 55,1 %). Під впливом різних за складом раціонів відбувались зміни якісних показників сала дослідних свиней, при цьому достовірно знижувався відсоток сухої речовини (до 2,84 %) і жиру (до 2,79 %) порівняно з контролем. Згодовування тваринам разом з раціоном, що містив важкі метали, експериментальної рослинної добавки, сприяло покращенню калорійності м'яса (до 19,4 %), сухої речовини (до 9,4 %), білково-якісного показника (до 5,9 %) порівняно із тваринами, що отримували з раціоном важкі метали, але без застосування цього технологічного прийому. Цей технологічний прийом сприяв також покращенню якісних показників сала тварин. А саме, відмічалось збільшення % сухої речовини (від 0,4 % до 2,5 %), жиру (від 0,7 % до 3,2 %) та зменшення клітинних оболонок у салі (від 8,6 % до 25 %) порівняно із показниками тварин II–IV груп та наближення їх до показників контролю

Ключові слова: свинина, сало, якість, важкі метали, вологоутримуюча здатність, експериментальна рослинна добавка

UDC 637.5'64.04/.05:636.087.72
DOI: 10.15587/1729-4061.2019.174154

STUDY OF QUALITY INDICATORS FOR MEAT RAW MATERIALS AND THE EFFECTIVENESS OF A PROTECTIVE TECHNOLOGICAL METHOD UNDER CONDITIONS OF DIFFERENT CONTENT OF HEAVY METALS IN A PIG DIET

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*Received date 11.06.2019
Accepted date 19.07.2019
Published date 09.08.2019*

1. Introduction

Under modern conditions of market relations, an important task of livestock breeding industry is not only to increase production, but also to ensure its high quality. The quality of livestock production is determined not only by the genetic features of animals and their keeping conditions, but also, to a greater extent, by the level of feeding, specifically, by balanced and high-quality feeds [1]. High quality products should not only provide the human body with the necessary amount of energy and nutrients, at the same time toxic and other unfavorable for human organism substances should not exceed the established norms. However, every year it is becoming increasingly difficult to achieve it against the background of the growing anthropogenic impact on the biosphere and the lack of effective measures of environmental safety [2, 3].

The factors that the animals did not face before get to the habitat of animals. These factors, first and foremost, include the increased content of chemical contaminants (heavy metals, dioxins, pesticides and others) in soil, feeds, etc. In this list, heavy metals and their compounds have become significantly spread in the environment, and their influence is becoming the most acute problem nowadays [4].

Heavy metals is the conventional name of the metals the density of which is more than 6 g/cm^3, relative atomic weight is more than 50 a. u. m, most of which are toxic (zinc, cadmium, mercury, chromium, lead and others); some people believe that these are the metals with atomic number of 20 a. u. m. and more [5].

These contaminants quickly migrate and are accumulated in the biosphere components (air, water, soil – plants – animals – humans), thereby hindering the production of high-quality agricultural products and have a negative impact on human health [6].

For a finished meat product to be considered organic, it must pass a long way from a farm to the counter with observance of the basic technological parameters of production [7]. And the first important stage in this process is the use of eco-friendly methods of agricultural production, specifically, livestock production. An important condition for the production of environmentally friendly products is keeping animals in environmentally clean areas. However, in the regions that are unfavorable in terms of the state of environmental pollution, high-quality raw material can be obtained only with the use of special technologies or their elements that ensure the production of environmentally safe meat products.

Thus, the expansion of modern ideas about ecological friendliness and quality of livestock products (pork) under conditions of chronic contamination with heavy metals is relevant. Along with this, the introduction of the element of the technology for organization of organic pig production is of great practical importance.

2. Literature review and problem statement

The paper presented the results of the study of the influence of diets of different composition on the quality of pork products (meat, lard), as well as proposed the element of the technology for production of organic animal products under conditions of technogenic contamination of feeds.

Under conditions of industrial livestock breeding, a disproportion of macro- and micro-elements in diets is becoming increasingly common, especially under conditions of the unstable environmental situation. This causes the animal developing diseases related to metabolism disorders and deterioration of the quality of animal products. This happens as a result of the use of low-quality synthetic feed additives and feeds obtained in the areas of anthropogenic pollution.

Today, the essential environmental contaminants include heavy metals, specifically, lead, mercury, cadmium and other [8].

According to the Food code designed by the board of the FAO and WHO, cadmium and lead are the most harmful of them. These elements, even in low concentrations, have expressed toxicological properties and lead to an increase in human diseases [9–11].

The main source of arrival of these micro-elements to the environment is the combustion of fuel, pesticides, some organic compounds, industrial wastes [12]. 94–97 % of lead, 84–89 % of cadmium arrive to the environment due to the anthropogenic sources [13].

At present, in the world there are the zones, in which the content of heavy metals in soil, water and plants exceeds the established norms, and the increased content of cadmium and lead in meat and dairy products has been revealed by many studies [14, 15]. That is why manufacturers of livestock production must minimize the risk of its contamination.

Heavy metals, arriving in the organism of animals not only reduce their productivity [16, 17], but also affect the chemical composition, indicators of biological value and sanitary quality of livestock breeding products [18].

The criteria that characterize the meat quality include the indicators of nutritional value, moisture-retaining capability, pH magnitude and the protein-quality indicator. These indicators depend on food quality and composition of feeds, as well as biological characteristics and physiological state of animals before being slaughtered [19]. It was found that at endemic diseases, the meat of animals often is contaminated with microflora, in connection with which it spoils more quickly in comparison with meat, obtained from healthy animals. In addition, the changes in indicators of quality and biological values of meat were found: protein content of muscle tissue decreases, and proteins of connective tissues – collagen and elastin increases [20].

Thus, under conditions of technogenic pollution of the agrosphere, manufacturers of livestock breeding products not always can guarantee biological value of meat raw material. Under such conditions it is necessary to follow the basic principles of organization and implementation of agricultural production on contaminated territories. These principles include the use of protective measures, directed, on the one hand, to reduction of consumption of hemotoxins with feed, on the other hand, to prevention of absorption of hemotoxins and acceleration of their excretion from animal organisms [21]. Development and implementation of protective measures is not possible without clear knowledge and in-depth ideas about toxicodynamics of hemotoxins and their impact on the quality of meat products.

The research into the influence of heavy metals on the quality of animal products in most papers is reduced to studying the level of accumulation of toxins in meat and internal organs of animals. In this case, the technological properties of meat, nutritional value and biological value of meat are not explored [22–24]. In addition, products are selected from the places where they are sold, which does not make it possible to know what amount of toxins arrived with feeds within the entire period of animal feeding [25].

Thus, the issues related to the study of the influence of diets with different contents of heavy metals on the quality of meat products remain unresolved. The reason for this is specific difficulties faced during conducting similar studies under production conditions, specifically, the presence of the required amount of feed containing the excessive amount of heavy metals and their appropriate ratio.

It is possible to overcome such difficulties by creating an imitation model of the ecocidic impact, that is, introduction to the feed of additionally required amount and ratio of heavy metals, which was used in the research.

The problem regarding the development and implementation of new technological measures, which make it possible to obtain high-quality, organic meat raw materials even in the face of excessive anthropogenic load, remains unresolved.

Today, there are many preparations that can prevent the negative effect of heavy metals, but they frequently have a number of disadvantages. The multiple effect of heavy metals on the body of the animal organism can not be eliminated by one component. Thus, natural adsorbents along with heavy metals actively excrete essential elements [26], synthetic preparations cause various side effects, which makes their long-term and preventive application impossible [27]. Application of integrated additives with natural components is new and promising in this direction, because it solves all these problems [2, 28].

In addition, based on the rule established by the EU, one implies by an organic product the product, the raw materials of which is by 95 % made up of the ingredients that have a certified organic origin [29].

All this makes it possible to assert that the creation of an artificial model of the ecocide influence under production conditions enables the promotion of the contemporary ideas about the quality and environmental safety of meat raw materials under conditions of technogenic contamination of feed. In addition, the study makes it possible to evaluate the technological method, specifically, the application of the experimental plant additive, with the purpose of cleaning meat raw materials from heavy metals and enhancing their quality.

3. The aim and objectives of the study

The aim of this study was to determine the indicators of quality for meat raw material under conditions of different content of heavy metals in the diet of pigs and to establish the effectiveness of the technological method, specifically, the application of the experimental plant additive as a protective measure.

To accomplish the aim, the following tasks have been set:

– to explore the changes in the nutritional and biological value of meat and lard of pigs during fattening under conditions of different content of lead and cadmium in the diet;

– to establish the features of technological properties of pork under conditions of different content of lead and cadmium in the diet;

– to evaluate the technological method (feeding the exe perimental additive) as the measure to enhance the quality of meat raw material under conditions of feed contamination with heavy metals.

4. Material and methods to study the influence of heavy metals on indicators of quality and safety of pig breeding production

To study the effects of elevated doses of lead and cadmium on the quality of meat raw materials and the efficiency of the technological method as a measure of improvement of the quality of pig breeding products, the model of ecocidal influence was artificially created. The studies were carried out throughout 2013 on the basis of the agricultural company that specializes in pork production. To do this, 5 groups including 10 castrated boars aged 4 months of large white breed were formed based on the principle of pairs-analogues. The basic diet of animals met the norms of swine feeding in terms of the level of energy nutrition and nutritive substances. Salts of heavy metals were added manually to the basic feed in the doses prescribed by scheme of the experiment (Table 1).

Table 1

Scheme of the experiment on studying the influence of heavy metals on products of pig breeding

Group	Number of heads in each group	Conditions of the experiment
Preparatory period (15 days)		
I–V	10	BD (basic diet) (content in feeds of Pb<5 mg/kg, Cd<0.4 mg/kg)
Basic period (139 days)		
I (control)	10	BD (content in feeds of Pb<5 mg/kg, Cd<0.4 mg/kg)
II (experimental)		BD+Pb in the dose of 20×MAC* (100 mg/kg of feed)
III (experimental)		BD+Cd in the dose of 20×MAC* (8 mg/kg of feed)
IV (experimental)		BD+Pb in the dose of 20×MAC* (100 mg/kg)+Cd in the dose of 20×MAC* (8 mg/kg)
V (experimental)		BD+Pb in the dose of 20×MAC* (100 mg/kg)+Cd in the dose of 20×MAC* (8 mg/kg)+experimental additive (30 g/per head/per day)

*Note: * – MAC is the maximum permissible concentration*

The animals of experimental group V were fed with the experimental plant additive along with contaminated feeds. This technological method was used during the whole period of fattening to prevent absorption and accelerate the elimination of heavy metals from the animal body.

The experimental additive contained the flour of medicinal herbs, oak extract, vitamins A, C, D3 and E, methionates of zinc, cuprum, cobalt and manganite.

All the animals were kept in the same technological conditions (number of animals in the group, breed and sexage structure, models of keeping and feeding). The groups differed in the form of the toxicant, which was assigned by a diet, the type of their action (aggregate and individual) and existence of the experimental additive.

At the end of the experiment, three heads of animals were selected from each group and control slaughter was executed. During the slaughter, the average sample of muscle tissue with the longest back muscle (700 g) and lard (200 g) were taken from each animal at the level of 9–12 thoracic vertebrae. The parameters of the chemical composition and physical and chemical properties of meat and lard were assessed for each animal individually (3 indicators for a group), and indicators between the groups were compared according to the average indicators for the group. The studies were conducted in the analytical laboratory of the Institute of livestock breeding of the NAAS.

The content of initial moisture in meat was determined by the Tomme method [30], which is based on the difference between the indicators of a batch of meat before and after drying and is calculated from formula (1):

$$X = \frac{100 \times a}{b \times 2}, \qquad (1)$$

where X is the percentage of initial moisture in the substance; a is the weight of water released at drying; b is the batch of a raw material.

The weight of dry matter in meat was estimated by the difference between the weight of the batch and the weight of moisture that was released when drying.

The content of raw inter-muscular fat was determined by the method of Lukashik N. and Tashchilin V. [31], which is based on releasing by ethyl ether of substances that are dissolved in ether. The protein content in meat was estimated by the Kieldall method [32].

The content of tryptophan was determined according to the method, modified by Katsukova A. A. [33], which is based on the fact that tryptophan provides in solution with dimethylamyobenzaldehyde-vapor in mineral acid the condensation product, which acquires blue color in the presence of nitric acid sodium.

The content of hydroxyproline was determined by the method, modified by Werbicki E. [34], according to which hydroxyproline is subject to oxidation after hydrolysis of the muscle fiber and the resulting oxidation product is determined by the color reaction with dimethylaminobenzaldehyde-vapor.

Moisture retaining capacity of meat was determined by the method, modified by Volovinska V. and Merkulova V. [35] based on the recalculation of the area of a wet spot, total moisture content in the batch (cm^2) and the weight of meat in the batch. Moisture capacity of meat was calculated from formula (2):

$$V = \frac{(A - 8.4B) \times 100}{M}, \quad (2)$$

where V is the content of bound moisture (in % to meat); A is the content of water in the batch, mg; B is the area of a wet spot, cm^2; M is the batch of meat, mg; 8.4 is the number obtained experimentally, which means the amount of absorbed moisture by 1 cm^2 of filtration paper.

The pH In water-meat extract was determined in the following way: a crushed meat sample of the weight of 10 g was put into a flask, 40 ml of bi-distilled water were added and set into a shaking device for 1 hour. The content of the flask was filtered through a folded filter, and the transparent extract was potentiometered at the pH-meter with a glass electrode.

During the laboratory studies, the following equipment was used: a digital laboratory balance with precision of 0.22 g, a household electric meat grinder with the diameter of grate openings of 2 mm and 4 mm, an electric drying chamber with a thermal regulator, metal and glass weighing bottles, glass sticks, filtration paper, distilled water, conical flasks and measuring cylinders.

The concentration of lead and cadmium in biological material was established on the atomic-absorption spectrophotometer of type AAS-30 (“Carl Zeiss Industrielle Messtechnik GmbH”, Germany). The principle of operation of this device is based on measuring the intensity of radiation or resonant absorption during the light passing through the atomic vapor of the studied sample at excitation in air-acetylene flame. The spectral range of the device of 185–900 nm provides the possibility of switching in the mode of atomic emission to detect alkali and alkali-earth metals.

The materials of research were treated with mathematical-statistical methods with the use of the packages of applied programs “Excel-2010” (Microsoft Corporation) and “Statistica-10” (Soft Stat Inc.) [36, 37].

5. Results of studying the indicators of quality for meat raw materials and the efficiency of a protective technological method under conditions of different content of xenobiotics in the diet of pigs

5. 1. Changes in nutritional and biological value of meat and lard of pigs during fattening under conditions of different content of lead and cadmium in the diet

As a result of the performed study, the indicators of the nutritional and biological values of the longest back muscle of the researched animals were studied. The analysis of these indicators revealed that the arrival of heavy metals from feed adversely affected the content of dry matter, fat, protein and these changes were more significant in animals of group IV (Table 2).

The content of dry matter in the meat of the animals of this group decreased by 2.72 % (P>0.99), fat and protein, respectively, by 1.44 % (P>0.99) and 1.5 % (P>0.99). These indicators decreased due to the increase in the amount of moisture in the meat, and it, respectively, was 76.05 % in group IV. In the meat of the animals that received heavy metals from feed, an increase in the content of ash in the range from 0.04 % to 0.2 % was noticed as compared with the control. This is due to the accumulation of lead and cadmium in the meat of animals, at that, the highest content of ash was noticed in animals from group IV.

A decrease in the caloricity of meat of the animals of groups II–IV of the experimental groups compared with the control was reliable and these changes ranged from 205.12 kcal (group II) to 289.8 kcal (group IV). The content of tryptophan in the meat of animals of these groups also decreased, which had an impact on the protein-quality indicator – it was the lowest in the animals of experimental group IV and was respectively 6.09.

Table 2

Quality of pork of the experimental animals, $M \pm m$, (n=3)

Indicators	Group of animals				
	I (control)	II	III	IV	V
Moisture, %	73.33±0.11	75.28±0.57*	75.44±0.27**	76.05±0.41**	73.79±0.16
Dry matter, %, including:	26.67±0.11	24.72±0.57*	24.56±0.27**	23.95±0.41**	26.21±0.16
fat	3.80±0.25	3.02±0.58	2.71±0.38	2.36±0.08**	3.73±0.22
protein	22.21±0.19	21.00±0.15**	21.05±0.26*	20.71±0.14**	21.74±0.24
ash	0.66±0.06	0.70±0.03	0.80±0.08	0.86±0.19	0.74±0.08
Caloricity of 1 kg of meat, kcal	1,357.40±17.26	1,152.28±8.47***	1,109.70±35.81***	1,067.60±14.80**	1274.50±18.13*
The ratio of tryptophan to hydroxyproline	6.64±0.09	6.41±0.02	6.36±0.10	6.09±0.09	6.45±0.17

*Note: probability of difference from control at *** – P>0.999, ** – P>0.99, * – P>0.95*

The influence of lead and cadmium resulted in the changes in qualitative indicators of lard of the experimental pigs (Table 3): the amount of dry matter decreased reliably (respectively, by 2.32 % and 2.84 %) and the amount of fat in lard decreased (respectively, by 2.69 % and 2.79 %) in the experimental animals of groups III and IV compared with the control.

Table 3

The quality of lard of the tested animals, *M*±*m*, (*n*=3)

Indicators	Group of animals				
	I (control)	II	III	IV	V
Dry matter, %	94.41±0.26	93.45±0.43	92.09±0.21**	91.57±0.34**	93.83±0.46
Moisture, %	5.59±0.26	6.55±0.43	7.91±0.21	8.43±0.34	6.17±0.46
% of cell membranes	3.59±0.14	3.25±0.34	3.96±0.40	3.51±0.29	2.97±0.13*
% of fat	90.82±0.38	90.20±0.49	88.13±0.45*	88.06±0.38**	90.86±0.50

*Note: the probability of difference from control at *** – P>0.999, ** – P>0.99, * – P>0.95*

In addition, under these conditions of nutrition there were the changes in cell membranes towards their increase and this indicator was the highest in animals of group III that received a diet with the excessive content of cadmium (3.96 %, at control of 3.59 %).

5. 1. Specific features of the technological properties of pork under conditions of different lead and cadmium content in the diet

Technological properties of meat of the studied pigs were determined by the moisture-retaining capability and active acidity (pH). The moisture-retaining capability of meat is determined by the amount of bound water in it and influences the output of finished products, juiciness and tenderness of meat. Good quality pork has the moisture retaining capability at the level of 53–66 %. According to the studies, this indicator in meat of the studied animals ranged from 55.10 % to 56.46 % and was within the norm for all the groups (Table 4).

One of the important factors that determine the quality of pork is acidity (pH). Active acidity determines the stage of meat maturity, its storage and suitability for processing. In alive muscles the reaction is close to neutral (pH is 7.0–7.2). 48 hours after the slaughter, mature meat of healthy animals has pH of 5.20–5.98. At an increase in pH (above normal) the composition of the microflora of meat changes and it gets spoiled very quickly. According to the results of the research, active acidity of meat of the animals in all groups was within the norm. However, pH in the animals that received elevated doses of heavy metals with feed slightly changed towards the neutral medium and these changes were probable in meat of the animals of experimental groups III and IV ($P>0.95$ and $P>0.99$).

Introduction of elevated doses of cadmium and lead into the diet of young pigs had an impact on the character of accumulation of metals-toxicants in the organs and tissues (Fig. 1–3).

The data of the graph presented in Fig.1 show that lead is mostly accumulated in the liver and the kidneys of the animals of research groups II and IV, in this case, MAC exceeded by 8.9 and 6.7 times in the liver and by 2.6 by 3.1 times in the kidneys, respectively. The accumulation of lead and cadmium in spleen and meat followed the same tendency, however, exceeding MAC in this organ and the tissue was lower: in the spleen of the animals of groups II and IV groups it was by 3.4 and by 1.8 times lower, in meat, respectively, by 1.9 and by 1.5 times lower. Thus, lead in the body of pigs was distributed in the organs and tissues of the animal research groups II and IV as follows: liver>kidneys>spleen>meat.

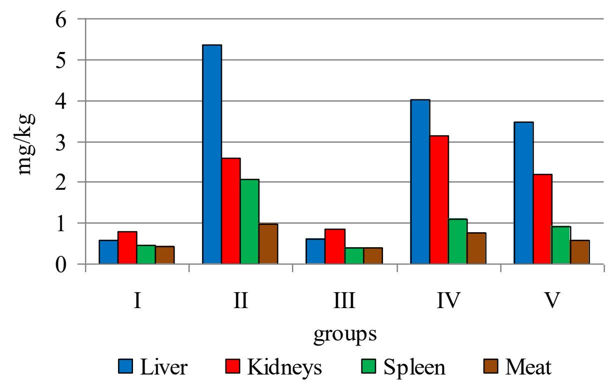

Fig. 1. Dynamics of changes in the content of lead in liver, kidneys, spleen and meat of pigs at different content of heavy metals in the diet, mg/kg

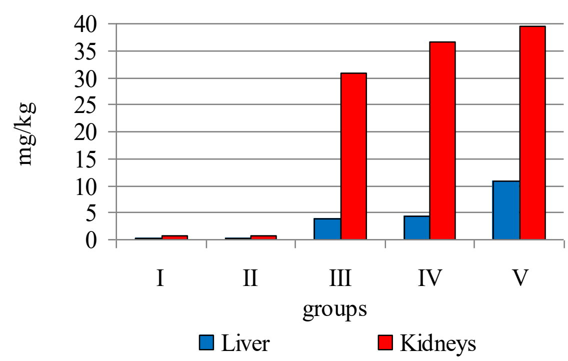

Fig. 2. Dynamics of changes on cadmium content in liver and kidneys of pigs at different content of heavy metals in the diet, mg/kg

Analysis of Fig. 2 reveals that cadmium is accumulated most in the liver and kidneys of the animals of research groups III–IV. MAC was exceeded in the liver in these groups by 6.50–18.25 times, and in the kidneys, respectively, by 30.8–39.6 times.

Table 4

Technological properties of the longest muscle of pigs, *M*±*m*, (*n*=3)

Indicators	Group of animals				
	I (control)	II	III	IV	V
Moisture retaining capability, %	55.10±7.62	55.46±0.15	55.93±0.13	56.46±0.10	55.69±3.08
Active acidity (pH)	5.12±0.03	5.27±0.06	5.45±0.09*	5.53±0.04**	5.27±0.08

*Note: the probability of difference from control at *** – P>0.999, ** – P>0.99, * – P>0.95*

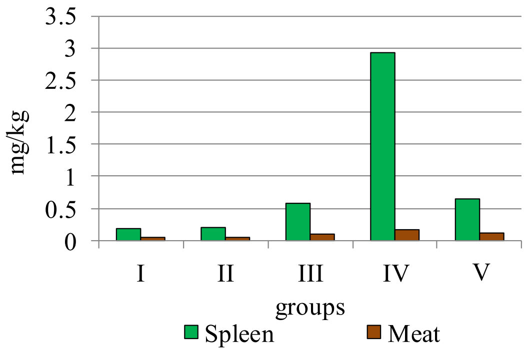

Fig. 3. Dynamics of changes of cadmium content in the spleen and meat of pigs at different content of heavy metals in the diet, mg/kg

In spleen and meat, cadmium (Fig. 3) is most accumulated in the animals of group IV, thus exceeding the MAC, respectively, by 9.7 times and by 3.2 times. Thus, the distribution of Cadmium in organs and tissues was as follows: kidneys>liver>spleen>meat.

5. 3. Effectiveness of the technological method for improving the quality of meat raw materials under conditions of technogenic contamination of feeds

In order to enhance the quality of meat raw material of animals that received the feed with the elevated content of lead and cadmium, the new technological method was applied. It involved feeding the animals throughout the entire period of fattening with the experimental additive along with feeds that contained heavy metals. Due to the plant component of the additive that had a multiple effect on the organism of the animals, the indicators of nutritional and biological values of meat improved. Specifically, dry matter in meat increased by 2.3 %, protein by 1.0 %, and fat by 1.4 % in comparison with the animals that were kept in the same conditions of feeding only without the additive (group IV). Meat caloricity increased by 206.9 kcal compared with the indicator of group IV and was almost equal to the control value.

Biological value of meat was determined by the amino acid composition of protein, specifically, the ratio of essential amino acid tryptophan to hydroxyproline. In the animals of the research groups, it ranged from 6.09 to 6.45 (in the control 6.64), in this case, it was the highest in the animals that received the experimental additive.

The components of the experimental additive also contributed to the improvement of the qualitative composition of lard of the animals. In particular, it was noticed that dry matter increased from 0.4 % to 2.5 %, fat from 0.7 % to 3.2 % and cell membranes in the lard decreased from 8.6 % to 25 % in comparison with the indicators of the animals of other research groups. The qualitative composition of lard of the animals that received the additive did not differ essentially from the indicators of the control, and for some indicators it was even higher: % of fat was higher by 0.04 %, and amount of cell membranes was lower by 0.62 %.

The technological properties of pork under the influence of the experimental plant additive did not change significantly, but there was a tendency of these indicators approaching the control ones. Thus, pH of the meat of the pigs that received an experimental additive was 5.27 and the maximum pH indicator of the animals of other research groups was 5.53, while the control value was 5.12.

The moisture retaining capability of meat of the animals of all research groups was within the norm and did not change essentially under the influence of either heavy metals, or additives. However, if we compare these indicators on the whole, the experimental additive decreased the moisture retaining capability of meat that increased under the influence of heavy metals.

6. Discussion of indicators of quality of meat raw materials and the efficiency of the protective technological method under conditions of different content of heavy metals in the diet of pigs

Receiving lead and cadmium with the feed, both jointly and separately, in the dose of 20 MAC had an impact on the nutritional and biological value, as well as on the technological properties of meat and lard of pigs. The content of dry matter in the meat of the animals that received heavy metals decreased from 1.95 % (P>0.95) to 2.72 % (P>0.99), fat and protein, respectively, from 0.78 % to 1.44 % (P>0.99) and from 1.21 % (P>0.99) to 1.5 % (P>0.99). These indicators decreased due to an increase in the amount of moisture and ash in meat.

The ash content increased in the range from 0.04 % to 0.2 %, which can be explained by the lead and cadmium accumulation in meat of the animals which were fed with toxins jointly.

A decrease in fat and protein in meat under the action of heavy metals influenced its caloricity. Thus, the caloricity of meat of the animals of experimental groups II–IV reliably decreased in the range from 205.12 kcal (group II) to 289.8 kcal (group IV) compared with the control.

The content of tryptophan in the meat of the animals of these groups also decreased, which had an impact on protein-quality indicator, it was the lowest in the animals of research group IV and was accordingly 6.09.

The main indicator of meat quality is the concentration of water ions (pH). This indicator depends on the content of glycogen in muscles at slaughter time and is a feature of the physiological state of animals before slaughtering, it also reflects the progress of after-slaughter processes in the tissues. The studies revealed that active acidity of meat of the animals in all groups was within the norm, but pH of meat of the pigs that obtained increased doses of heavy metals with the feeds slightly changed towards the neutral medium. This may indicate the changes in the composition of the microflora of meat and become the cause of its rapid spoiling.

In addition to active acidity, such technological indicator of meat quality as the water retaining capability was also determined. This indicator is determined by the amount of bound water in it and influences the output of finished products, juiciness and tenderness of meat. According to the studies, this indicator in the meat of the research animals ranged from 55.10 % to 56.46 % and was within the norm for all the groups.

The study of qualitative indicators of lard of the pigs, obtained under the conditions of the experiment showed that under the influence of heavy metals the amount of dry matter decreased (from 0.96 % to 2.84 %) and so did the amount of fat (from 0.62 % to 2.76 %) in lard compared with the animals from the control group. This decrease was due to an increase in moisture content and % of cell membranes.

The above-mentioned data indicate a significant negative influence of heavy metals not only on the quality of the meat raw materials, but also on the technological properties of pork. In other words, under conditions of excessive content of chemotoxicants in feeds it is not possible to obtain high-quality products and a compulsory measure is to control the content of heavy metals in the feeds consumed by animals.

The application of the new technological method (application of the experimental plant additive) against the background of using excessive doses of heavy metals by animals made it possible to improve the indicators of the chemical composition of meat (contents of dry matter, protein and fat), caloricity, protein-quality indicator. These indicators improved in comparison with the animals from groups II–IV and approached the level of control. The components of the experimental additive positively influenced the quality indicators of lard, specifically, contributed to an increase in the percentage of dry matter, fat, and a decrease of cell membranes in lard.

The positive action of the additive is explained by the pharmacological properties of its components. The additive contains a complex of natural ingredients (medicinal plants, vitamins, methonates of microelements), the combination of which provides binding toxins in the organism and their rapid excretion, the activation of the immune and antioxidant systems, normalization of metabolism, as well as strengthening of the organism in general.

Thus, this technological method may be a protective measure that improves the quality of meat raw material under conditions of anthropogenic contamination of feed with heavy metals.

The obtained results of the research extend the modern idea of the effect of feeds with the excessive content of heavy metals on the indicators of quality of meat raw material, manufactured under conditions of agricultural production. In addition, they prove the expediency of using the experimental additive as the technological method with the aim of restoring the quality of livestock products if feeds contain chemotoxicants.

The main advantage of this study over the analogues is that it was conducted on animals, which have production values, and production from them is widely used. In addition, the research was carried out under production conditions by creating an artificial model of the ecocidal influence. This makes it possible to recommend the companies that manufacture animal products under conditions of technogenic contamination to use the studied technological method as a protective measure for obtaining high-quality products of pig breeding.

The obtained data enable anticipation of the impact of xenobiotics, such as lead and cadmium, on the quality of meat raw material, specifically, nutritional and biological value and the technological properties of meat and lard of pigs. Practical significance of these data is that they may be used when carrying out the environmental assessment of technologies and during designing the production technologies of animal breeding under conditions of technogenic contamination. The results of the study emphasize the need for the application of protective measures in the production of high-quality animal products. Specifically, to monitor the content of toxicants in feeds and to apply new technological methods of prevention of accumulation and acceleration of elimination of chemotoxicants from the organism of animals.

The conducted research is limited to studying only qualitative indicators and technological properties of meat and lard of young pigs for fattening. It might be interesting to explore the meat flavor properties, the content of xenobiotics and the degree of their accumulation in lard, as well as the changes that will occur at these indicators in the study of other sex-age groups of animals. However, these are large-scale studies and cause a series of complications while performed under production conditions.

7. Conclusions

1. It is proved that the influence of feeds with the elevated content of heavy metals resulted in changes in the qualitative indicators for meat and lard of pigs. Thus, the content of dry matter in the meat of the animals that received heavy metals decreased from 1.95 % ($P>0.95$) to 2.72 % ($P>0.99$), fat and protein, respectively, from 0.78 % to 1.44 % ($P>0.99$) and from 1.21% ($P>0.99$) to 1.5 % ($P>0.99$). Meat caloricity decreased up to 21.3 % (group IV) and protein-quality indicator up to 8.3 % (group IV). The percentage of dry matter and fat in the lard of the animals that received the elevated doses of heavy metals reliably decreased, these changes were especially significant in the animals of research groups III and IV.

2. It was found that a slight shift of the pH level towards neutral medium was observed in meat of the animals that received feeds with the high content of heavy metals. The moisture retaining capability of meat of the tested animals ranged from 55.1 % to 56.5 %, at 55.1 % in the control.

3. The positive effect of the applied technological method in order to improve the properties of meat raw materials under the conditions of technogenic contamination of feeds was established. The experimental additive contributed to an increase in the content of dry matter (up to 2.3 %), protein (up to 1.0 %) and fat (up to 1.4 %) in meat, meat caloricity (up to 19.4 %), the protein-quality indicator (up to 5.9 %) compared with the animals that received heavy metals without receiving the additives with feeds. This technological method also contributed to the improvement of the qualitative indicators of lard of the animals and their approaching the control indicators: an increase in dry matter (up to 2.5%), fat (up to 3.2 %) and a decrease of cell membranes in lard (up to 25 %) in comparison with the indicators of animals of other research groups.

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