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DETERMINING THE MEDICAL AND BIOLOGICAL SAFETY OF MEAT-CONTAINING POLYCOMPONENT PRODUCTS BASED ON REGIONAL RAW MATERIALS

This paper reports medical and biological studies of semi-finished meat product and meat-containing semi-smoked sausage on laboratory rats. The purpose of the study was to investigate the effect of the developed products on the dynamics of live weight, the state of internal organs and tissues, general and biochemical parameters of the blood of animals when they are introduced into the standard diet in the amount of 30 %. The studies were conducted on 30 white nonlinear rats weighing 145–150 g, of which one control and two experimental groups were formed, according to the principle of the method of analog groups.

It is proved that the introduction of meat-containing multicomponent products with a high protein content into the diet of rats in the amount of 30 % of the standard diet contributes to the intensification of animal growth processes. It was confirmed that the increase in live body weight of rats after 21 days of the experiment amounted to 33–38 %, which is larger than that in control by 69–90 %.

No negative impact on the state of the internal organs of rats from the consumption of the developed products was detected.

It was found that the inclusion of meat-containing multicomponent products in the diet of rats contributes to an increase in erythropoiesis by 12.66 % compared to the starting data. The inclusion of products in the diet does not significantly change the content of leukocytes and platelets while increasing blood saturation with hemoglobin by 45.83–58.33 % higher compared to control animals.

The introduction into the diet of laboratory rats of meat-containing multicomponent products has an anabolic effect and contributes to an increase in the concentration of hemoglobin by 42.12 %, total protein by 4.79 %, creatinine by 19.68 %. In laboratory rats, there is a decrease in glucose by an average of 8.17 %, which indicates an intensification of processes in muscle tissue. Enhanced protein synthesis due to increased catabolism leads to an increase in bilirubin concentration by 19.12–21.97 % compared to control rats. Medical and biological studies of meat-containing multicomponent products can be applied in practice to confirm their safety

Keywords: functional ingredients, meat-containing multicomponent products, dynamics of live weight, biochemical parameters of blood

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1. Introduction

Food intake and the environment are two main factors that influence the state of health and the development of painful conditions of the person [1]. Research in nutrition has improved understanding of how to maintain the health of a group of people living under different dietary conditions [2, 3]. Healthy food is an integral part of a healthy lifestyle, but consumer employment often interferes with gaining access to an optimal diet. Increased interest in determining the relationship between diet, dietary ingredients, and health led to the development of functional foods [4, 5]. In addition, recent studies confirm the link between diet and prevention of many diseases, including genetically determined [6, 7]. As a result, the range of products and semi-finished products that meet the requirements of consumers for high-quality, healthy and safe nutrition, the preparation or use of which significantly saves time on cooking, has significantly expanded.

Reducing the physical activity of the population requires taking into account the protein-energy balance of food. Therefore, functional products based on the use of raw materials of plant origin and multicomponent protein-containing compositions are of particular importance [8]. At the same time, a relevant task in the field of food technology is the use of traditional and non-traditional protein-containing raw materials. Taking into account the functional and technological characteristics and biological value of raw materials makes it possible to ensure effective balancing of amino acid and fatty acid composition of products for certain categories of consumers, to take into account the personalization of the patient's nutrition [8].

When developing multi-ingredient functional products, the principles of combinatorics are used to take into account the possible functional addition of the constituent ingredients of the raw materials.

It is the combination of components of different origin and, accordingly, of different chemical composition that makes it possible to model products with specified characteristics. Nevertheless, there is a problem of creating not only a healthy, nutritious, and healthy product, but ensuring its food safety during the production and use of finished products. Therefore, determining biomedical safety of the developed multicomponent products is relevant for the food industry.

2. Literature review and problem statement

The authors of [9] note a link between nutrition and the development of diseases such as obesity, diseases of the cardiovascular system, cancer, high blood pressure and diabetes of the second type. This is determined not only by a certain eating behavior but also by a decrease in physical activity, mainly by the hypodynamic nature of employment, etc. [9]. Ultimately, this leads to higher health care costs and a decrease in the quality of life. Modern conditions and life expectancy are also associated with various mental health problems such as depression, poor concentration, and memory loss [10]. There is a problem of the development of metabolic diseases in people leading an unhealthy lifestyle, which can be solved by correcting the diet through the inclusion of functional foods in the diet.

For the prevention of metabolic diseases and in order to correct painful conditions through the diet, in the food industry a new direction has been defined – the production of food for the intended purpose. The production of food for the intended purpose in the use of regional raw materials of nutrition, containing in its composition dietary fiber, essential amino acids, minerals, and vitamins is gaining popularity. Consumption of targeted foods will help reduce the incidence of the population due to its preventive action and ensure healthy nutrition of people with insufficient quantity or quality of traditional products.

For the development of targeted products with the widest possible range of nutrients and essentials, it is important to introduce functional ingredients of plant, animal, and microbiological origin into the recipe. The advantage of such products is that they include natural ingredients and are used as components of diets. These functional products include antioxidants, dietary supplements, fortified dairy and meat products, citrus fruits, as well as vitamins, minerals, herbs, plant extracts, milk, and cereals [11]. They can include a wide range of phytochemicals such as phytoestrogens, phytosterols, terpenoids, carotenoids, limonoids, polyphenols, anthocyanidins. In addition, they act as nutraceuticals and have a specific pharmacological effect on human health [12]. The actual problem is the development of multifunctional foods of multi-ingredient composition, as well as the optimal selection of components for the formulations of meat-containing products.

The problem of protein resources for meat-containing products for the intended purpose is solved by combining raw materials of animal and vegetable origin. Meat products are associated with a negative health image mainly due to the high content of cholesterol and saturated fatty acids (SFA up to 50 % in beef, about 40 % in pork). In addition, in meat products, taking into account the technological specifics of production, there is a high content of sodium chloride [13]. The presence of these components increases the risk of obesity, cardiovascular disease, coronary artery disease, some types of cancer and hypertension, which causes consumers to be skeptical of meat [14]. Therefore, it is proposed to reduce the share of red meat in meat formulations at the expense of other protein sources [15]. Despite the sufficient amount of plant protein resources, the problem of selecting and combining alternative meat protein ingredients of high nutritional value remains unresolved.

The source of animal protein in multicomponent functional products can be marine or freshwater aquaculture, poultry meat. Freshwater fish and waterfowl meat are not inferior to traditional types of red meat in nutritional and biological value, and also have high functional and technological indicators. In works [16, 17], it is proposed to develop a technology for the production of meat-containing semi-smoked sausages with freshwater fish protein, namely white silver carp, silver crucian carp, in combination with duck meat. It was found that the protein content in the developed sausages with different ratios of duck meat and fish is 17.90–21.34 % higher than in an analog. A sausage containing 50 % duck and 30 % fish has an ideal protein: a fat ratio of 1:1. High functional properties of model minced meat of experimental semi-smoked sausages have been proved: humidity – up to 72.75 %, water binding capacity – up to 71.47 %, water holding capacity – up to 60.60 %. A comparative analysis of the structural and mechanical indicators of minced meat showed that an increase in the proportion of duck meat in the systems of model minced meat improves their rheological characteristics. However, to ensure the required texture of products with the possibility of introducing vegetable protein-containing components and their effects when combining vegetable, fish and poultry meat, further research is necessary.

The use of protein ingredients of plant origin has been widely adopted. In addition to traditional soybeans and products of its processing, the protein ingredient can be the products of processing technical hemp. Hemp seeds, which are raw materials for flour and protein concentrate, have a high protein content of up to 40 %. This raw material contains about 38 % of proteins balanced in amino acid composition, including lysine, tryptophan, leucine, phenylalanine. Hemp seed processing products are a source of dietary fiber (up to 15 %) [18]. In [19], it is proved that the addition of hemp flour to the recipe of meat-containing products improves the consumer value of products by increasing the content of protein, fat, and mineral elements. It has been experimentally confirmed that the introduction of hemp flour into the composition of meat systems improves their functional and technological indicators. This raw material is effectively combined in the composition of minced meat with semi-fat pork, poultry meat mechanically rolled from turkey, increasing the plasticity of minced meat. The medical and biological safety of combining hemp products with meat ingredients and other vegetable proteins remains an unexplained issue.

A group of popular functional ingredients for the meat processing industry is polyphenols in plant extracts. High efficiency in preventing oxidative processes during long-term storage of meat-containing products was shown by extracts of berries, rosemary, red grapes [20, 21]. The addition of these extracts to minced meat during the preparation of products makes it possible to slow down the oxidative processes during storage at the stage of hydrolytic breakdown of fats. In addition, it reduces the proportion of stale products and components of secondary lipid oxidation, extends shelf life by reducing the rate of oxidative spoilage of the product. However, the safety of combining antioxidant preparations with other components of multicomponent meat-containing products remains unexplored.

From the analysis of the literature, it follows that the problem of the validity of decisions regarding the possibility of combining ingredients of different composition and origin in the recipes of multicomponent meat-containing products remains unresolved. The reason for this is the lack of data from biomedical studies of the developed multicomponent meat-containing products. The combination of food ingredients of different origins in the composition of food products requires confirmation of their food safety for consumers in the processes of production and storage.

3. The aim and objectives of the study

The aim of this study is to determine the safety of meat-containing multicomponent products based on regional raw materials based on the results of medical and biological research. This will make it possible to introduce such products into industrial production.

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

– to investigate the dynamics of the live weight of experimental animals during the experiment to confirm the biological usefulness and food safety of the developed meat-containing multicomponent products;

– to investigate the indicators of the general blood test of laboratory animals during the experiment to determine the impact on these indicators of the qualitative and quantitative composition of the developed products during their consumption;

– to study and analyze the biochemical parameters of the blood of laboratory animals during the experiment, depending on the duration of consumption of the developed meat-containing multicomponent products.

4. The study materials and methods

A series of experimental works was carried out on warm-blooded test objects – 30 mature white nonlinear rats (males) with an initial weight of 145–150 g, at the Romny Interdistrict Veterinary Laboratory, Sumy oblast (Ukraine). A control group of 10 animals and two experimental groups of laboratory animals of 10 individuals each were formed. Groups of animals were formed by random sampling, taking into account body weight as a determining indicator. The animals were quarantined and acclimatized under vivarium conditions for 14 days. The test product was administered in the amount of 30 % of the basic standard diet (Table 1).

The feeding and all other manipulations with animals were carried out in compliance with the standards of the European Convention for the Protection of Animals. The standards were adopted by the First National Congress of Ukraine on Bioethics; animal manipulation was carried out in accordance with [22–25].

The procedure of slaughter and bleeding was carried out taking into account the ethical approaches and rules established by the UN "World Charter of Nature" (1982) and in accordance with the Law of Ukraine "On Protection of Animals from Ill-Treatment" as of 21.02.2006.

All groups of animals were kept under standard vivarium conditions in compliance with a 12-hour darkness/light lighting regime with unrestricted access to drinking water and feed. The animals received a standard full-fledged balanced granulated feed for laboratory rats, which provided their body's physiological needs for vitamins, trace elements, minerals, and energy. In the experimental groups of rats, 30 % of the minced meat of the developed combined products (minced semi-finished products and semi-smoked sausages) were added to the main feed.

In order to avoid the influence of random factors on the results of further biochemical and hematological studies, all animals were under the same conditions of detention. Tables 1, 2 provide data on the formulations of meat-containing multicomponent products that were used in studies on rats.

Table 1

Formulation of minced semi-finished products for clinical trials on laboratory rats

Constituent components	Quantity, kg or g per 100 kg
Silver crucian carp (minced meat), kg	30.5
Duck meat, kg	30.5
Wheat bread, kg	12.0
Breadcrumbs, kg	4.0
Onions, kg	1.5
Chicken eggs, kg	2.0
Ground pepper, kg	0.06
Table salt, kg	1.2
Water for soaking bread, kg	18.3
Rosemary extract, kg	0.15

When conducting experiments, we daily monitored the general condition of animals, the consumption of food and water, and once a week determined body weight.

When analyzing the habitus of rats, we noted the liveliness of temperament, natural prostration of the body, and average fatness. No radical changes in appearance and behavior have been recorded. The coat was quite thick, shiny, and inherent in this type of animal in a normal physiological state, the claws were not deformed, hard. The body temperature of animals of all groups was normal (37–38 °C), the respiratory rate was 85–90 per minute. However, it should be noted that after the first 7 days of research, appetite and coat condition improved in animals from the study groups. At the end of the experiment (on the 22nd day), the animals in the experimental groups were distinguished by thicker and shiny hair compared to the control ones.

Table 2

Recipe of semi-smoked sausages for clinical trials on laboratory rats

Constituent components	Quantity, kg or g per 100 kg
Duck meat, kg	50
Minced fish (silver carp meat), kg	30
Side fat, kg	10
Soy isolate, kg	4
Hemp protein, kg	6
Salt, g	2,874
Granulated sugar, g	100
Black pepper, g	100
Sodium nitrite, g	5
Nutmeg or ground coriander, g	50
Fresh peeled garlic, g	200
Cranberry extract, kg	0.2

Feeding was carried out strictly at the same time daily, the usual daily diet did not change. In almost all groups, the first to eat food were larger individuals, and then all the others. Experimental groups first ate meat products, and then proceeded to the usual diet. Table 3 provides data on the structure of the daily diet of experimental groups of rats.

Table 3

The structure of the daily diet of experimental groups of rats

Group of rats	Quantity, pcs.	The composition of the daily diet
Control	10	full balanced granulated feed
Experiment 1	10	full balanced granulated feed + 30 % minced meat of semi-finished products
Experiment 2	10	full balanced granulated feed + 30 % minced sausage

Throughout the experiment, observations and measurements of the water consumed were carried out. The control group consumed 17–21 % more water than animals of the experimental groups. At the same time, animals behaved actively, had a good appetite, were not afraid of man. During the observation period, the hair of the animals of the experimental groups changed more intensely and became shinier, the nose and legs were pink, the eyes were clean.

The study of blood serum indicators of animals was carried out in dynamics every 7 days of the experiment (on 7, 14, and 21 days).

To conduct blood tests using biochemical and hematological analyzers, blood was selected by puncture of the caudal vein. To do this, the tail was warmed with warm water, and after disinfecting, the vein was pinched at the edge of the tail, the needle was inserted into the vessel and the right amount of blood was extracted with a syringe.

To obtain plasma, blood was taken from test tubes with a previously applied anticoagulant (1 % heparin solution). Plasma was separated by centrifugation at 1500 rpm for 15 min. After sampling, the blood was analyzed on an automatic hematological analyzer no later than 2 hours later.

Determination of hematological parameters, namely the total number of leukocytes, the total number of red blood cells, hemoglobin content, platelet count was carried out on an automatic hematological analyzer (Orphèe Mythic 18, Switzerland).

Statistical processing of the results was carried out using the standard package of software Microsoft Excel (USA), using Student's *t*-criterion. A difference was considered probable if the value of $p<0.05$.

5. Results of medical and biological studies of meat-containing products when introduced into animal rations

5. 1. Results of studies of the dynamics of live weight and the state of the internal organs of laboratory animals

To assess the effect of introducing the developed semi-finished products and semi-smoked sausages into the diet of laboratory rats on animal morphometry, studies were conducted on the dynamics of the live weight of rats during the experiment. The research results are given in Table 4.

In the first and last days (on the 21st day) of the study, measurements of the body weight of rats were carried out. Thus, before the start of the experiment, the weight of the control rats was at the level of 156.13 g, in experimental group 1 – 151.47 g, and in experimental group 2 – 159.63 g.

On the 7th day after the start of the experiment, changes in live body weight were noticeable, in all experimental groups the weight gain was as follows (g) – in control, by 5.54 g; in experimental group 1 – 11.76 g, in experimental group 2 – 9.44 g.

Table 4

The average mass of rats of the control and study groups during the experiment, g (M±m)

Indicator	Control	Experiment 1	Experiment 2
At the beginning of the experiment	156.13±8.55	151.47±9.75	159.63±4.97
On the 7th day of the experiment	161.67±1.35*	163.23±3.2	169.07±2.87
On the 14th day of the experiment	161.23±3.17	161.67±1.35*	163.23±3.2*
Ha 21 day of experiment	187.5±7.31	209.31±9.87	213.99±5.33
Absolute gain	31.37±5.18	57.84±3.98	54.27±4.83
Relative increase, %	20.09	38.18	33.96

*Note: *P>0.95*

In subsequent control periods, there was also a more intense increase in the live weight in the rat study groups, compared with the control group. Absolute growth gain of the live weight of rats of the control group during the observation period was – 31.37±5.18 g, experimental group 1 – 57.84±3.98 g, and group 2 – 54.27±4.83 g. Relative increase in the live body weight during the observation period was 19 % in the control, in experiment 1 – 30 %, and in experiment 2–31 %.

At the pathologic anatomical autopsy of all experimental groups of rats, pathologies of internal organs were not detected. Genitals without visible pathologic anatomical changes. The blood corresponded to a dark red color, well folded. The lungs were slightly wet, light pink in color. The liver and kidneys matched their size and color. The heart also had its shape and color, without any deviations. The entire digestive system had no visible pathologies.

5. 2. Results of studies of the general blood test of laboratory animals

The results of the study of general blood indicators are given in Table 5.

Analysis of general blood parameters during the experiment showed that the erythrocyte content in the blood of control and laboratory animals practically did not change. However, with an increase in the concentration of hemoglobin in the blood of laboratory rats, the saturation of red blood cells with this respiratory protein has changed, which is confirmed by the color index of the blood. At the end of the experiment, the saturation of red blood cells with hemoglobin in animals that consumed experimental meat-containing products increased to 1.05–1.14, which is 45.83–58.33 % higher compared to control animals. The number of leukocytes in the blood of animals practically did not change during the entire experimental period, which indicates the absence of inflammatory processes in the body of animals.

5. 3. Results of studies of the biochemical blood indicators of laboratory animals during the experiment

The results of the study of biochemical blood parameters of laboratory animals during the experiment are given in Table 6.

The hemoglobin content in the blood of control animals ranged from 12.09–12.72 mmol/dm^3 and remained virtually unchanged during the experimental period. In animals receiving the experimental diet, the hemoglobin concentration was constantly increasing and at the end of the experiment reached 17.64–17.89 mmol/dm^3, which is on average 42.12 % higher than that in the control group. The total protein content in control animals was 71.58±0.39 g/dm^3 at the end of the experiment, while in laboratory rats it ranged from 74.26±0.71 to 75.01±0.18 g/dm^3, which is 4.79 % higher.

During the experiment, there was an increase in the level of creatinine in the blood, which on the 21st day of the experiment in the study groups fluctuated at 73.0973.21 mol/dm^3, which is 19.68 % higher compared to the control group. The detected level of creatinine in the blood corresponds to the norm.

Cholesterol levels in laboratory animals fluctuated within the normal range. During the experiment, cholesterol concentration did not change significantly compared to the original data at the beginning of the experiment. Thus, the level of cholesterol ranged, on the 21st day of the experiment, from 2.22±0.03 in control animals to 2.24±0.03 mol/dm^3 in animals of the 2nd experimental group.

Table 5

Indicators of the general blood test of laboratory animals during the experiment

Indicator	Norm	Control			Experiment 1			Experiment 2		
		Day 7	Day 14	Day 21	Day 7	Day 14	Day 21	Day 7	Day 14	Day 21
Red blood cells, 10^{12}/l	6–9	7.11±0.97	7.11±0.97	7.09±0.63	7.11±0.93	7.11±0.17	7.47±0.11	7.11±1.0	7.11±0.57	8.01±0.11*
Platelets, 10^9/l	800–1400	1221±3.85	1221±3.85	1221±3.15	1220±5.61	1217±4.33	1217±2.87	1222±5.87	1220±3.09	1220±3.01
Leukocytes, 10^9/l	4.0–17	5.27±0.17*	5.31±0.11*	5.31±0.11*	4.36±0.21	4.55±0.09	4.55±0.09	4.39±0.01*	4.31±0.09*	4.31±0.09*
Color indicator	0.85–1.05	0.72	0.72	0.73	0.78	0.82	1.05	0.84	0.85	1.14

*Note: *P>0.95*

Table 6

Biochemical parameters of the blood of laboratory animals during the experiment

Indicator	Norm	Control			Experiment 1			Experiment 2		
		Day 7	Day 14	Day 21	Day 7	Day 14	Day 21	Day 7	Day 14	Day 21
Bilirubin, μM/dm^3	00.0–1.67	0.91± ±0.03	0.91± ±0.03	0.91± ±0.03	1.01± ±0.01*	1.11± ±0.01*	1.11± ±0.01*	0.91± ±0.01*	1.09± ±0.03	1.09± ±0.03
Creatinine, mol/dm^3	68.0–104.0	59.87± ±0.93	59.16± ±0.17*	61.17± ±1.08	67.20± ±2.13	69.20± ±1.27	73.21± ±0.87	74.07± ±1.15	72.09± ±1.03	73.09± ±1.16
Hemoglobin, mmol/dm^3	11.0–17.0	12.72± ±1.87	12.71± ±1.13	12.09± ±3.57	13.82± ±4.85	14.57± ±2.44	17.64± ±1.13	14.97± ±3.16	14.99± ±0.67	17.89± ±1.27
Cholesterol, mol/dm^3	2.2–2.6	2.21± ±0.03*	2.21± ±0.03*	2.22± ±0.03*	2.19± ±0.07*	2.07± ±0.11	2.04± ±0.01*	2.21± ±0.11	2.11± ±0.07	2.24± ±0.03
Glucose, mmol/dm^3	3.3–5.56	4.07± ±0.03	4.03± ±0.17	4.03± ±0.17	3.76± ±0.18	3.71± ±0.03*	3.79± ±0.23	3.71± ±0.57	3.70± ±0.37	3.79± ±0.17
Urea, mmol/dm^3	3.2–8.0	5.73± ±0.11	5.63± ±0.11	5.47± ±0.16	4.46± ±0.23	5.77± ±0.12	5.73± ±0.19	4.37± ±0.40	5.71± ±0.09*	5.73± ±0.77
Total protein, g/dm^3	65–85	73.86± ±0.83*	73.86± ±0.83*	71.58± ±0.39*	74.19± ±1.03	75.03± ±0.35*	74.26± ±0.71*	74.39± ±0.96	74.88± ±0.4*7	75.01± ±0.18*

*Note: *P>0.95*

In the study of the concentration of glucose in the blood, it was found that its level at the beginning of the experiment was at almost the same level in all laboratory animals. However, already in the first week of the experiment, there was a tendency to reduce the concentration of blood glucose in animals from the 1st and 2nd experimental groups. When removed from the experiment, in animals the glucose level was 4.03±0.17 in the control group, and 3.79±0.23 mmol/dm^3.

The bilirubin content during the experiment in all animals fluctuated within the normal range. Nevertheless, after the first week of the experiment, there was a tendency to increase the concentration of bilirubin in laboratory animals. Thus, in rats of the first group on the 21st day of the experiment, the concentration of bilirubin was 1.11±0.01 μm/dm^3, which is 21.98 % more compared to the control.

6. Discussion of results of investigating the dynamics of live weight, general and biochemical blood parameters of laboratory animals

During the experiment and the introduction into the diet of a meat-containing minced semi-finished product and meat-containing semi-smoked sausage, all laboratory animals felt satisfactory. Analysis of the dynamics of weight gain in the animals indicates that in animals of all groups it increased during the experiment relative to the initial data. At the same time, the increase in body weight in experimental groups increased more significantly compared to intact animals of the control group, which indicates an increased digestibility of the developed products and their high nutritional value. The greatest increase in body weight was observed in animals of the second experimental group (Table 4). This is due to the partial 30 % replacement of the standard diet for minced sausage meat-containing semi-smoked sausage with duck and freshwater fish meat and hemp vegetable protein, which is a source of high-grade protein. There were no abnormal differences between the two experimental groups that received semi-finished and sausage minced meat with partial introduction to the diet. The larger gains in the live weight of animals in the second group are due to the higher concentration of protein in the recipe for sausage minced meat, which was combined with freshwater fish meat, waterfowl, soy isolate, and hemp protein. This is consistent with the data from [26], which showed that white and red meat proteins have a greater positive effect on the growth of young rats compared to soy protein.

At the autopsy of rats, it was proved that the use of meat and vegetable product by animals from the minced meat composition does not affect the body of animals. The study of the weighting coefficients of the internal organs of animals (liver, kidneys) did not reveal deviations of these indicators from the corresponding values in the control group, which indicates the absence of morphological changes on the part of the hepatorenal system.

It has been established that the feeding of animals that is full and balanced in all nutrients and essential substances determines their state of health and productivity. The main nutrients and macro- and microelements are crucial for the functioning of the animal's metabolome and are involved in the formation and development of internal tissues and organs, including in hematopoiesis [27].

In the animals of all groups, the number of red blood cells fluctuated within the physiological norm. At the same time, in the animals of the second group at the end of the experiment, the number of red blood cells increased significantly (by 12.66 %) in relation to the initial data. Obviously, this is due to the stimulation of erythropoiesis by the components of the experimental product, namely the sources of protein of animal and vegetable origin. This proves the expediency of introducing into the formulation of meat-containing products of a multicomponent combination of protein ingredients. The number of leukocytes fluctuated within the physiological norm throughout the experiment in animals of all groups. There was a tendency to reduce the number of leukocytes in laboratory animals, which indicates a more physiological combination of components and the presence of animal protein in the diet of animals. This has a positive effect on DNA methylation during the development and aging of animals whose diet contains a sufficiently high level of nutrients, in particular, meat proteins [28].

The blood system is the most labile and sensitive to the effects of negative environmental factors. Studies have shown that during the experimental period in laboratory animals there was a tendency to increase the concentration of hemoglobin in the blood. In the animals that received the experimental diet, the concentration of hemoglobin increased and at the end of the experiment reached 17.64–17.89 mmol/dm^3, which is on average 42.12 % higher than that in the control group. This trend indicates the anabolic effect of the proposed products, which led to an increase in hemoglobin synthesis and an increase in blood transport and respiratory function, which is confirmed by studies [29]. An increase in the hemoglobin concentration in animals also indicates a higher level of redox processes in the body.

Our data are consistent with the dynamics of the indicator of the total amount of protein in the blood.

In the animals that received meat-containing products of a multicomponent composition, an increase in the concentration of creatinine in the blood was noted. At the end of the experiment, its level in the research groups was 73.09–73.21 mol/dm^3, which is 19.68 % higher compared to the control group. Also, the concentration of creatinine increased compared to the beginning of the experiment, which is explained by an increase in the level of amino acid and energy metabolism, the intake of the essential amino acid methionine. Creatinine is a product of energy metabolism in muscles, synthesized from creatine, which, in turn, is formed from the essential amino acid methionine, as well as arginine and glycine [30, 31].

During the study of the level of cholesterol in the blood of laboratory animals, a slight increase in this indicator was noted within the normal range relative to the initial data. This indicates the absence of hypercholesterolemic effect in the proposed foods, which stand out for their high protein content and low lipid concentration.

In laboratory rats, there is a decrease in glucose by an average of 8.17 %, which indicates an intensive metabolism due to intensification of processes in muscle tissue and increased energy metabolism due to aerobic glycolysis [32]. The developed products contain significantly less polysaccharides compared to the standard diet, so introducing them into the diet for rats leads to a decrease in the breakdown of grain starch and, accordingly, reduces the level of glucose circulating in the blood.

Bilirubin is a breakdown product of hemoglobin, which is metabolized in the liver and excreted from the body with the help of bile [33]. With the introduction of high-protein products into the diet of laboratory rats, the synthesis of proteins in the liver, including hemoglobin, is intensified. This leads to increased breakdown of the main transport protein of the blood. Due to a change in diet in laboratory rats that received meat-containing foods during the 21st day, bilirubin levels increased by 19.12–21.97 % compared to control rats.

The limitations of the study include the lack of investigation into the antioxidant status of rats that received meat-containing multicomponent products, which include substances with an antioxidant effect, which is necessary to fully characterize the safety of the product. The prospect of further research is to determine the indicators of the antioxidant system of the body of laboratory animals, which are introduced into the diet of developed products.

According to the results of studies on rats, the developed multicomponent meat-containing products are proposed to be used for the industrial production of health food products for different segments of the population. The most promising direction in the development of such products is probably the production of meat-containing chopped semi-finished products. This group of products can be produced at restaurant establishments, as well as at meat processing enterprises.

7. Conclusions

1. It is proved that the introduction into the diet of rats in the amount of 30 % of the standard diet of meat-containing multicomponent products with a high protein content contributes to the intensification of animal growth processes. It was confirmed that the increase in the live body weight of rats after 21 days of the experiment amounted to 33–38 %, which is more than in the control by 69–90 %. The negative impact on the state of the internal organs of rats of the consumption of the developed products has not been identified, which confirms the biological usefulness and nutritional safety of the developed meat-containing multicomponent products.

2. It was found that the inclusion of meat-containing multicomponent products in the diet of rats in an amount of up to 30 % contributes to an increase in erythropoiesis by 12.66 % compared to the initial data. The inclusion of products in the diet does not significantly change the content of leukocytes and platelets, increases blood saturation with hemoglobin by 45.83–58.33 % higher compared to control animals.

3. The introduction into the diet of laboratory rats of meat-containing multicomponent products has an anabolic effect and contributes to an increase in the concentration of hemoglobin by 42.12 %, total protein by 4.79 %, creatinine by 19.68 %. In laboratory rats, there is a decrease in glucose by an average of 8.17 %, which indicates an intensification of processes in muscle tissue. Enhanced protein synthesis due to increased catabolism leads to an increase in bilirubin concentration by 19.12–21.97 % compared to control rats. This confirms the safety and positive effect of the use in the diet of developed meat-containing multicomponent products.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

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