Potravinarstvo Slovak Journal of Food Sciences

OPEN ACCESS

Received: 1.4.2024
Revised: 20.5.2024
Accepted: 17.7.2024
Published: 20.8.2024

Slovak Journal of Food Sciences

Potravinarstvo Slovak Journal of Food Sciences
vol. 18, 2024, p. 683-696
https://doi.org/10.5219/1976
ISSN: 1337-0960 online
www.potravinarstvo.com

Expanding the range of fortified meat products through the targeted combination of raw materials of animal and vegetable origin

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ABSTRACT

The problem of providing the population with a full-fledged balanced diet is currently quite acute worldwide. Therefore, one of the main tasks is to expand the range of fortified and functional food products, including those with prebiotic effects. The article presents the results of developing fortified boiled sausages, liver pates, and chopped semi-finished products, which have high consumer properties, nutritional and biological value, organoleptic characteristics, and a balanced nutritional composition. The minimum amino acid score value for the proposed boiled sausages is 95.6%, and, for liver pate – 99.6%, for chopped semi-finished products – 88.1%. The biological value of the protein of the developed products reaches 92.8%, 87.7%, and 99.7%, respectively. This is achieved through specially selected components of animal and vegetable origin. Meat and meat-plant products were developed based on an analysis of the nutritional status of North Caucasus Federal University students. The optimal formulation was determined, and the nutrient balance of the finished products was ensured using computer modelling. Using dry milk molasses with lactulose "LactuVet-1" in the formulations of fortified meat products made it possible to increase their organoleptic characteristics and enrich them with calcium (about 150 mg per 100 g of finished product) and other minerals. The developed meat products contain lactulose, g/100 g of product: boiled sausages – 0.46, chopped semi-finished products – 0.61, liver pate – 0.76. This helped to ensure the prebiotic effect of the finished product. The proposed meat products are a source of vitamin A and calcium, contain most B vitamins, macroelements potassium and magnesium, and microelements iron and zinc. The complex of tasks to reduce the deficit of the main types of nutrients, revealed during the study, can be solved by including the developed meat products in the diet of the target group of consumers.

Keywords: functional foods, meat product, lactulose, milk molasses, nutrient balance

INTRODUCTION

An unbalanced diet is one of the global problems of modern urbanised society. This leads to alimentary-dependent diseases. **[1]**, **[2]**, **[3]**. Introducing a variety of high-quality food into the diet and using products with a balanced composition of nutrients are two main ways to solve this problem **[4]**. The first way can be implemented in conditions of daily consumption of various high-quality food products of animal and vegetable origin without financial difficulties. The second way can be successfully implemented if there is a publicly available range of food products balanced in amino acids, lipids, vitamins, and minerals. Food products like these can be enriched with bioactive and functional ingredients to neutralise negative factors that affect human health through their diet **[5]**. The balance of nutrients in food products must necessarily be related to the physiological needs of a certain group of consumers or a specific person. **[6]**. The second way is the most realistic and accessible when considering the world's economic situation and the lifestyle of a modern person.

Therefore, the most important task is to expand the range of fortified food products **[7]**, including meat products. This can be achieved by including high-quality functional ingredients in formulations, using low-cost secondary raw materials, and improving production technologies that ensure a maximum balance of finished products according to nutrients.

One effective direction in the selection and provision of the preventive orientation of new types of fortified and functional food products is the assessment of the nutritive (nutritional) status of the target consumer **[8]**, **[9]**, as well as the use of food ingredients with lactulose **[10]**, **[11]**, which can have a favourable effect on the human body through selective stimulation of the growth and activity of intestinal microflora **[12]**.

According to the results of analytical studies of the nutritive status of young people aged from 18 to 27 years (students of the North Caucasus Federal University), using computer modelling we developed recipes and technologies for such products as fortified cooked sausage products, liver pate and chopped meat and vegetable semi-finished products.

Scientific Hypothesis

The targeted combination of selected types of meat, vegetable raw materials, and functional ingredients using computer modelling will significantly increase the availability of finished meat products with high-grade protein, vitamins, and micro- and macroelements. This will achieve a prebiotic effect and high organoleptic characteristics.

MATERIAL AND METHODOLOGY

Samples

Raw materials of animal origin: veneered beef of the first grade, pork veneered semi-fat, side shpik, pork skin emulsion, duck meat, chicken meat, mechanically deboned chicken meat, beef liver, Bovine protein VT-Pro (collagen fibrilar), chicken eggs.

Raw materials of vegetable origin: carrots, onions, semolina, white cabbage, sweet pepper, rapeseed and soy oil, wheat bran, breadcrumbs, ground black pepper and allspice. Functional ingredients: mushroom powder from champignons, kelp, dry milk molasses with lactulose "LactuVet-1".

Chemicals

Hydrogen peroxide H_2O_2 according to GOST 177-88 (Medical class A, analytical grade, manufacturer: Russia), nitric acid HNO_3 according to GOST 4461-77 (analytical grade, manufacturer: Russia), sulfuric acid H_2SO_4 according to GOST 2184-2013 (analytical grade, manufacturer: Russia), phenol C_6H_6O according to the Technical conditions 6-06-5303-86 (analytical grade, manufacturer: Russia), ethanol C_2H_6O according to GOST 5962-2013 (excise duty, analytical grade, manufacturer: Russia), sodium nitroprusside $C_5FeN_6Na_2O$ according to GOST 4 218-48 (analytical grade, manufacturer: Russia), sodium hydroxide NaOH according to GOST 4328-77 (analytical grade, manufacturer: Russia), sodium hypochlorite NaClO according to GOST 11086-76 (grade A, manufacturer: Russia), distilled water H_2O according to GOSTP 58144 (analytical grade, manufacturer: Russia), standard solutions of carbohydrates arabinose, glucose, ribose, mannose, galactose, fructose, xylose, sucrose, lactose (analytical grade, Supelco USA), state standard samples of the composition of aqueous solutions of sodium, potassium, magnesium and manganese ions (analytical grade, manufacturer: Russia), caesium chloride (analytical grade, manufacturer: Russia), lanthanum chloride 7-aqueous (analytical grade, manufacturer: Russia), hydrochloric acid according to GOST 3118 (analytical grade, manufacturer: Russia), citric acid (analytical grade, manufacturer: Russia), phenolphthalein according to the Technical conditions 6-09-5360 (analytical grade, manufacturer: Russia), sodium N, N-diethyldithiocarbamate (analytical grade, manufacturer: Russia), copper sulfuric acid copper sulfuric acid according to GOST 4165 (analytical grade, manufacturer: Russia), lead nitric acid according to GOST 4236 (analytical grade, manufacturer: Russia), granular zinc according to the Technical conditions 6-09-5294 (analytical grade, manufacturer: Russia), cadmium metal (analytical grade, manufacturer: Russia), acetic acid ester according to GOST 22300 (analytical grade, manufacturer: Russia), calcone (eriochrome blue-black) (analytical grade, manufacturer: Russia), trilon B according to GOST 10652 (analytical grade, manufacturer: Russia), potassium hydroxide according to GOST 24363 (analytical grade, manufacturer: Russia), sodium citric acid, three-substituted, 5.5 aqueous according to GOST 22280 (analytical grade, manufacturer: Russia), hydroxylamine hydrochloride according to GOST 5456 (analytical grade, manufacturer: Russia), calcium carbonate according to GOST 4530 (analytical grade, manufacturer: Russia), technical chloroform according to GOST 20015 (analytical grade, manufacturer: Russia), acetone according to GOST 2603 (analytical grade, manufacturer: Russia), state standard samples of the composition of the selenium ion solution (analytical grade, manufacturer: Russia), hexane (analytical grade, manufacturer: Russia), hydrochloric acid $HClO_4$ (analytical grade, manufacturer: Russia), ammonia is aqueous (analytical grade, manufacturer: Russia), potassium carbonate according to GOST 4221 (analytical grade, manufacturer: Russia), potassium iodide according to GOST 4232 (analytical grade, manufacturer: Russia), sodium sulphate 5-aqueous according to the Technical conditions 6-06-2540-87 (analytical grade, manufacturer: Russia), bromine according to GOST 4109 (analytical grade, manufacturer: Russia), soluble starch according to GOST 10163 (analytical grade, manufacturer: Russia), sodium carbonate according to GOST 83 (analytical grade, manufacturer: Russia), isobutane according to the Technical conditions 6-09-1708-77 (analytical grade, manufacturer: Russia).

Animals, Plants and Biological Materials

Raw animal and vegetable origin materials for research were purchased at a grocery store in Stavropol of Russian Federation. Bovine protein (collagen fibrilar 99%) produced on JSC "Volga Tannery" (Ostashkov, Tver region, Russian Federation, 172735, Declaration of conformity TS N RU D-RU.AY08.V.00745). Dry milk molasses with lactulose "LactuVet-1" produced on JSC "Dairy Plant" Stavropol (Stavropol, Stavropol region, Russian Federation, 355036, Declaration of conformity of the EAEU N RU D-RU.A21.V.03469/20).

Instruments

Total Protein Analyzer Kjeldahl UDK-149 (VELP Scientifica, Usmate, Italy), Memmert UFB 400 drybox (Memmert, Germany), Vilitek ASV-6M semi-automatic Soxhlet apparatus (Vilitek LLC, Moscow, Russia), Muffle furnace L 9/11/SKM (Nabertherm, Germany), liquid analyzer "Fluorat-02" (Lumex, Russia), liquid chromatography (HPLC) SHIMADZU LC-20AD Prominence (Shimadzu, Japan), MGA-915 atomic absorption spectrometer (Lumex, Russia), SF-102 spectrophotometer (Aquilon, Russia), analytical balance Sartorius A 120 S (SARTORIUS, Germany).

Laboratory Methods

Students' nutritional status was assessed using the computer program "Monitoring of Physical Development and Nutritional Status" **[13]**. Formulation modelling, computer analysis of the nutrient composition, calculation of the amount of saturated (EFAs), monounsaturated (MNFA), and polyunsaturated (PUFA) fatty acids, indicators of amino acid balance, biological value of protein, nutritional and energy value of finished products were carried out using the Etalon software package **[14]**, **[15]** following the methodology of multilevel modelling of food systems **[16]**.

The mass fraction of moisture in meat products was determined by drying in a drying cabinet at a temperature of 103 ±2 °C according to GOST 9793-2016 **[17]**. The mass fraction of the protein was determined by the Kjeldahl method **[18]**, the mass fraction of fat by the Soxlet method **[19]**, **[20]**, the mass fraction of ash by the method of salting in a muffle furnace **[21]**. The composition and mass fraction of carbohydrates were determined using high-performance liquid chromatography according to GOST 34134-2017 **[22]**. The mass fraction of vitamins was determined using high-performance liquid chromatography according to GOST R 55482-2013 **[23]** and GOST 32307-2013 **[24]**. The flame atomic absorption method determined the mass fraction of potassium, magnesium, zinc, and iron according to GOST 55484-2013 **[25]** and GOST 30178-96 **[26]**. The titrimetric method determined the mass fraction of calcium according to GOST R 55573-2013 **[27]**. The mass fraction of phosphorus was determined by the spectrophotometric method according to GOST 9794-2015 **[28]**. The mass fraction of selenium was determined by the fluorimetric method of M 04-33-2004 **[29]**. The titrimetric method determined the mass fraction of iodine according to Guidelines 4.1.1106-02 **[30]**.

Description of the Experiment

Sample preparation: During physico-chemical tests, point samples weighing 200 g were taken from sausage products, cutting off from the product in the transverse direction at a distance of at least 5 cm from the edge. Of the two-point samples from different production units, a combined sample weighing 400 g was made. From several point samples, two combined samples with a mass of 400 g were made. For liver pates, two combined samples weighing 600 g were made. To prepare samples from chopped semi-finished products, four culinary products weighing 75 g were ground twice in a meat grinder and mixed to obtain a homogeneous mass. The prepared samples were placed in dry glass jars and tightly closed with lids. Before each sample was taken, the contents of the jar were thoroughly mixed. The samples were stored at a temperature of 4 ±2 °C until the end of the tests.

Number of samples analyzed: In the computer modelling process, 610 formulations of the studied meat products were calculated and analysed. Five recipes of each type of meat product (boiled sausages, liver pate, and chopped semi-finished products) with the best values of nutrient balance indicators were obtained from modelling. Based on the development and testing results, one recipe for each type of meat product was selected, the properties of which are presented in this article. Eighteen samples were analysed during physicochemical tests.

Number of repeated analyses: All measurements of the indicators on the devices were carried out at least three times.

Number of experiment replications: Each experiment was repeated at least three times to determine one value of each indicator.

Design of the experiment: In the first stage, based on an assessment of the nutritional status, a lack of basic nutrients in the diet of North Caucasus Federal University students was revealed. Nutritional status was assessed by completing questionnaires on anthropometric data, physical activity, and diet. 265 students participated in the study. Balanced formulations of boiled sausages, liver paste, and chopped semi-finished products with high nutritional and biological value were developed using computer modelling to solve the problem of reducing nutrient deficiency in the diet of the target group of consumers. Experimental developments and physicochemical tests of meat product samples were carried out at the last stage of the research stage.

Statistical Analysis

During the research, a set of standard methods for determining the physicochemical properties of finished products was used. The reliability of the results is confirmed by repeated repetitions and reproducibility of experimental data, their statistical processing, and approbation of the technology of new meat products in laboratory conditions of the Faculty of Food Technology and Engineering named after Academician A.G. Khramtsov of the North Caucasus Federal University. Statistical analysis was performed in Microsoft Excel 2019 using XLSTAT statistical software. The authenticity of the obtained experimental data for all indicators was determined using the Student's test with a confidence probability of ≤ 0.05 for the number of parallel determinations of at least three.

RESULTS AND DISCUSSION

The need to develop fortified food products and their inclusion in the diet of the category of consumers under study has been confirmed by our research, the results of which have shown that the vast majority of young people have a nutritional deficiency of vitamins, as well as a deficiency of the main types of mineral substances, including calcium, potassium, magnesium, iron, zinc, selenium and iodine. A deficiency of B vitamins in the diet was found in 45% of young people, while vitamin A deficiency was found in 61% of young men and 77% of young women. Most consumers studied have a nutritional deficiency of vitamins C, E, and D. More than 64% of young people have insufficient calcium in their diet, and iodine deficiency was detected in more than 82% of the study participants (Figure 1).

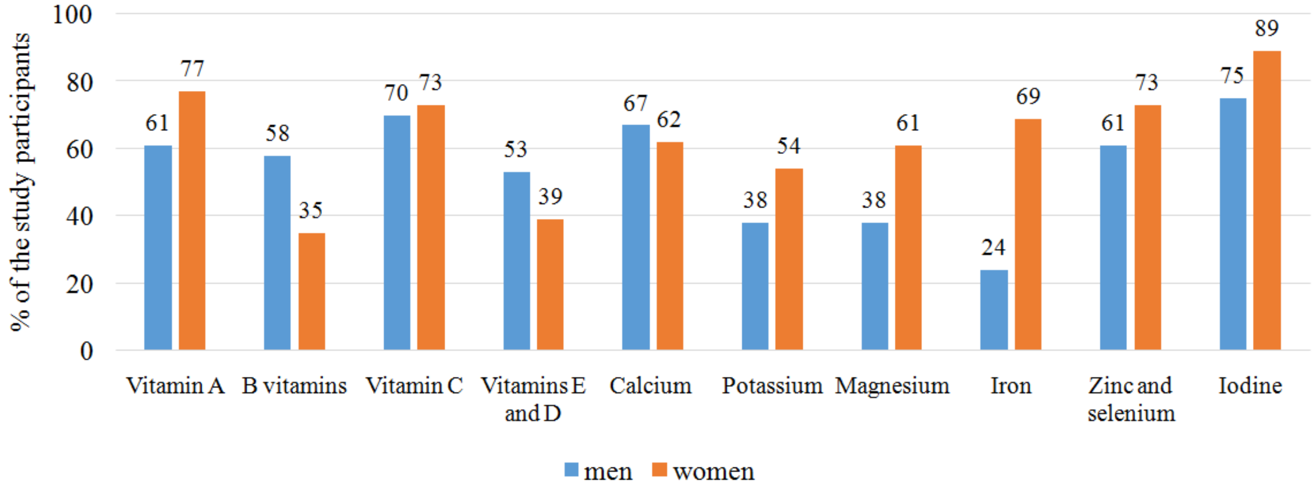

Figure 1 The lack of vitamins and minerals in the diet of the studied group of young people.

Most male and female respondents consume an excess of saturated fatty acids (SFAs) per day – 54% and 68%, respectively. At the same time, 61% of the studied men and 74% of female respondents are deficient in polyunsaturated fatty acids (PUFA).

To overcome the identified deficiency of nutrients, formulations of many meat and meat-vegetable products have been developed and proposed within the research framework. The composition of the developed cooked sausage includes veneered beef of the first grade, pork veneered semi-fat, pork skin emulsion, nitrite salt, and ground and allspice pepper. The recipe also includes chicken fillet, chicken eggs, and mushroom powder from champignons as an additional source of protein **[31]** and to give the product a nutrient balance of amino acid composition, increase the stability of consumer properties, nutritional, biological value, and organoleptic characteristics.

Dry milk molasses with lactulose "LactuVet-1" is proposed as a source of prebiotics, sweetening agents, and micro- and macroelements in the formulation **[11]**. Kelp was used to enrich cooked sausage with iodine in an easily digestible form **[32]**.

Dry milk molasses with lactulose "LactuVet-1" is a product of deep processing of whey, has a low cost, and contains at least 14.3% lactulose, 25.2% lactose, 15.0% mineral substances, including 3.4% calcium, 1.4% phosphorus, 1.2% potassium, 0.5% magnesium **[33]**. It is obtained by manufacturing high-quality crystalline milk sugar (lactose). Dry milk molasses with lactulose "LactuVet-1" is a dry powder of light yellow or cream color, with a neutral odor characteristic of the raw material from which it is made.

The introduction of dry milk molasses with lactulose "LactuVet-1" and kelp in the recipe of cooked sausage enriches the product with mineral substances, including calcium, magnesium, phosphorus, potassium **[33]**, and iodine **[34]**, **[35]** due to their mutual combination and specially selected quantitative ratio.

The results of studies of boiled sausage are shown in Table 1.

Table 1 Physico-chemical parameters of the developed boiled sausage.

Name of indicators	Values
Mass fraction of moisture, %	66.7 ±0.9
Mass fraction of protein, %	10.3 ±0.4
Mass fraction of fat, %	15.7 ±0.9
Mass fraction of carbohydrates, %	2.9 ±0.5
Mass fraction of ash, %	3.56 ±0.15
Mass fraction of lactose, %	0.78 ±0.06
Mass fraction of lactulose, %	0.46 ±0.04
Energy value, Kcal/KJ	194/943

Developed cooked sausages contain not less than 0.42 grams of lactulose in their composition (in 100 grams) **[36]**, which corresponds to 20% of the minimum recommended daily intake of this prebiotic **[12]**. It is known **[37]** that lactulose retains its structure and bifidogenic activity during thermal processing in the production of food products **[38]**.

The high degree of balance of boiled sausage in terms of amino acid composition is confirmed by a sufficiently high value of the generalized desirability criterion (0.73 units) **[14]**, this corresponds to a rating of "good" on the Harrington desirability scale **[39]**, **[40]**. The minimum amino acid score value is 95.6%, and the biological value of the proposed product reaches 92.8% (Table 2).

Table 2 Indicators of amino acid, fatty acid balance, and biological value of the protein of the developed boiled sausage.

Name of indicators	Values
Generalized desirability criterion for essential amino acids **[14]**, percentage of units	0.73
Minimum amino acid score, %	95.6
Comparable excess ratio **[14]**, g/100g protein	3.8
Coefficient of difference of amino acid score **[14]**, %	7.2
Biological value of protein **[14]**, %	92.8
EFAs, g/100 g lipids	38.3
MUFAs, g/100 g lipids	34.5
PUFAs, g/100 g lipids	10.9

Note: The values of the indicators were calculated using the Etalon computer program.

Table 3 shows data on micro-, macronutrients, and vitamins in the developed product.

Table 3 Content of micro-, macronutrients and vitamins in boiled sausage.

Nutrient	Contents per 100 g of sausage	% of the RDA*
Vitamins		
Vitamin A, retinol equivalent, mg	0.141 ±0.012	15.7/17.6**
Vitamin B1, thiamine, mg	0.161 ±0.023	10.7
Vitamin B2, riboflavin, mg	0.214 ±0.041	11.9
Vitamin B3, niacin, mg	2.605 ±0.154	13.0
Vitamin B5, pantothenic acid, mg	0.285 ±0.039	5.7
Vitamin B6, pyridoxine, mg	0.167 ±0.029	8.4
Vitamin B12, cobalamin, mcg	0.337 ±0.083	11.2
Macronutrients		
Potassium, mg	346.19 ±30.81	9.9
Calcium, mg	153.04 ±16.98	15.3
Magnesium, mg	37.85 ±5.30	9.0
Phosphorus, mg	152.33 ±7.76	21.8
Micronutrients		
Iodine, µg	45.28 ±6.70	30.2
Iron, mg	0.979 ±0.123	9.8/5.4**
Zinc, mg	0.878 ±0.142	7.3
Selenium, mcg	15.56 ±2.53	22.2/28.3**

Note: *RDA – recommended daily requirement for over 18 of age by MR 2.3.1.0253-21 «Norms of physiological requirements in energy and food substances for different population groups of the Russian Federation»; ** values RDA for men/women.

The presented results of studies of the nutrient composition of the developed boiled sausage indicate that the product meets the needs of the target consumer group and fills the identified deficiency of the main types of vitamins and mineral substances.

The main raw materials of the developed pate recipe are beef liver, carrots, bacon, chicken skin, rapeseed and soya oil, onion, mushroom powder from mushrooms, dry milk molasses with lactulose (LaktuVet-1) **[11]**, **[33]**, semolina, and bone broth. Computer modelling and optimisation of the ratio of these components in the developed pate allowed the product to have consistently high consumer properties, balanced nutrient composition, and prebiotic action.

The useful properties of mushroom powder from dried champignon are determined primarily by its nutritional value. Mushrooms have a special chemical composition **[41]**; they are characterised by the content of a large number of vitamins, macro-, and microelements, and contain a significant amount of organic salts and sugars **[42]**, **[43]**. The useful properties of mushroom powder also manifest themselves in its saturation of vegetable protein **[44]**. It is digested by the body better than whole mushrooms and contains B vitamins, ascorbic acid, calcium, magnesium, and other vitamins and micro- and macronutrients **[45]**.

Soya oil contains 70% PUFAs **[46]**. It is also a source of vitamin E (17.1 mg per 100 g of product) **[47]**. Introducing soya oil into a new type of pate formulation increases the mass fraction of vegetable fat and useful unsaturated fatty acids **[48]**.

Rapeseed oil, which contains high polyunsaturated and monounsaturated fatty acids (MUFAs), is also used in the pate recipe **[49]**. MUFAs have a positive effect on reducing bad cholesterol and normalising heart function **[50]**. In addition, rapeseed oil contains a significant amount of a powerful antioxidant – vitamin E (18.9 mg per 100 g of product) **[48]**.

Finely ground chicken skin has a low production cost and is well suited for improving the visco-plastic properties of liver pate. The fat-soluble vitamins in chicken skin are vitamins A and D. The water-soluble ones are vitamins B1, B2, B3 (PP), B5, B6, B9, and B12. Its mineral composition is represented by macronutrients: potassium, magnesium, sodium, and phosphorus; and trace elements: iron, zinc, and selenium **[51]**.

Fortified liver pate contains at least 35.5% of the recommended daily intake of the prebiotic lactulose. Its energy value is 286 kcal, of which 15.1% is protein. This indicates that this product can be classified as a source of protein **[52]**.

Physicochemical quality parameters of the developed liver pate are presented in Table 4.

Table 4 Physico-chemical quality indicators of the developed pate.

Name of indicators	Values
Mass fraction of moisture, %	57.4 ±0.8
Mass fraction of protein, %	10.8 ±0.4
Mass fraction of fat, %	24.9 ±0.6
Mass fraction of carbohydrates, %	4.7 ±0.5
Mass fraction of ash, %	2.20 ±0.04
Mass fraction of lactose, %	1.29 ±0.06
Mass fraction of lactulose, %	0.76 ±0.05
Energy value, Kcal/KJ	286/1198

The developed pate has a high degree of balance in amino acid composition, which is confirmed by the value of the generalised desirability criterion (0.67 units), corresponding to a score of (good) on Harrington`s desirability scale **[39]**, **[40]**. At the same time, the value of the minimum amino acid score is 99.6%, and the biological value of the proposed product reaches 87.7% (Table 5).

Table 5 Indicators of amino acid, fatty acid balance and biological value of the protein of the developed pate.

Name of indicators	Values
Generalized desirability criterion for essential amino acids **[14]**, percentage of units.	0.67
Minimum amino acid score, %	99.6
Comparable excess ratio **[14]**, g/100g protein	4.5
Coefficient of difference of amino acid score **[14]**, %	12.4
Biological value of protein **[14]**, %	87.7
EFAs, g/100 g lipids	31.9
MUFAs, g/100 g lipids	33.4
PUFAs, g/100 g lipids	32.6

Note: The values of the indicators were calculated using the Etalon computer program.

Analysis of the data in Table 5 shows that by TR CU 022/2011 **[52]**, the developed liver pate has a high content of vitamins A, B2, and B12. It is a source of iron, calcium, phosphorus, and vitamins E, B3, and B5, therefore fulfilling the stated purpose of covering their deficiency in young people.

The recipes of the developed functional meat and vegetable semi-finished products with prebiotic action contain duck meat and mechanically deboned chicken meat in an optimally selected ratio, beef protein, carrots, white cabbage, sweet pepper, dry milk molasses with lactulose, semolina, egg powder, soybean oil, wheat bran, breadcrumbs, and spices.

The energy value of the developed semi-finished products is 177.8 kcal, of which 22.8% is provided by protein. It allows them to be classified as food products with a high protein content. The product contains the prebiotic lactulose (at least 28.5% of the recommended daily intake, Table 6).

Table 7 shows the pate's micro-, macronutrients, and vitamin content.

Table 6 Physicochemical quality indicators of chopped semi-finished products.

Name of indicators	Values
Mass fraction of moisture, %	65.1 ±0.9
Mass fraction of protein, %	10.2 ±0.5
Mass fraction of fat, %	11.2 ±0.6
Mass fraction of carbohydrates, %	1.68 ±0.05
Mass fraction of ash, %	1.05 ±0.05
Mass fraction of lactose, %	0.61 ±0.04
Mass fraction of lactulose, %	744.4/177.8

Table 7 Content of micro-, macronutrients and vitamins in liver pate.

Nutrient	Content in 100 g in the pate	% of the RDA*
Vitamins		
Vitamin A, retinol equivalent, mg	3.474 ±0.112	386/434**
Vitamin B1, thiamine, mg	0.111 ±0.016	7.4
Vitamin B2, riboflavin, mg	0.781 ±0.148	43.4
Vitamin B3, niacin, mg	4.434 ±0.212	22.2
Vitamin B5, pantothenic acid, mg	1.704 ±0.106	34.1
Vitamin B6, pyridoxine, mg	0.270 ±0.044	13.5
Vitamin B12, cobalamin, mcg	19.94 ±4.18	664.7
Vitamin C, mg	5.860 ±0.375	5.9
Vitamin D, calciferol, mcg	0.29 ±0.04	1.9
Vitamin E, alpha-tocopherol, mg	2.301 ±0.068	15.3
Macronutrients		
Potassium, mg	309.23 ±28.45	8.8
Calcium, mg	150.32 ±18.18	15.0
Magnesium, mg	35.68 ±4.71	8.5
Phosphorus, mg	202.44 ±10.02	28.9
Micronutrients		
Iron, mg	2.433 ±0.212	24.3/13.5**
Zinc, mg	1.345 ±0.191	11.2

Note: * RDA – recommended daily requirement for over 18 of age following MR 2.3.1.0253-21 (Norms of physiological requirements in energy and food substances for different population groups of the Russian Federation); ** values RDA for men/women.

The new types of chopped semi-finished products have a high balance of essential amino acids. The generalised desirability criterion for essential amino acids of the product is close to the reference value equal to one. The indicators in Table 8 indicate a high biological value of chopped meat and pastry semi-finished products.

Table 8 Indicators of nutrient balance, nutritional and energy value of meat and vegetable semi-finished products.

Name of indicators	Values
Generalized desirability criterion for essential amino acids **[14]**, percentage of units.	0.96
Minimum amino acid score, %	88.1
Comparable excess ratio **[14]**, g/100g protein	4.5
Coefficient of difference of amino acid score **[14]**, %	0.31
Biological value of protein **[14]**, %	99.7
EFAs, g/100 g lipids	25.1
MUFAs, g/100 g lipids	37.1
PUFAs, g/100 g lipids	25.7

Note: The values of the indicators were calculated using the Etalon computer program.

The combination of meat, vegetable raw materials, and functional ingredients made it possible to most significantly provide the developed food product with protein, PUFAs, vitamins, micro-, and macroelements, where the ratio of calcium and phosphorus is close to optimal. At the same time, the ratio of calcium and phosphorus in the developed semi-finished products is close to the optimal (1:1) for calcium assimilation **[53]** (Table 9).

Table 9 The content of micro-, macroelements, and vitamins of meat and vegetable semi-finished products.

Nutrient	Content in 100 g in the semi-finished products	% of the RDA*
Vitamins		
Vitamin A, retinol equivalent, mg	0.138 ±0.011	15.4/17.3**
Vitamin B1, thiamine, mg	0.065 ±0.010	4.3
Vitamin B2, riboflavin, mg	0.095 ±0.021	5.3
Vitamin B3, niacin, mg	2.089 ±0.113	10.5
Vitamin B5, pantothenic acid, mg	0.341 ±0.042	6.8
Vitamin B6, pyridoxine, mg	0.113 ±0.020	5.7
Vitamin B12, cobalamin, mcg	8.297 ±0.473	8.3
Vitamin C, mg	0.16 ±0.03	1.1
Vitamin D, calciferol, mcg	0.665 ±0.040	4.4
Macronutrients		
Potassium, mg	198.50 ±21.84	5.7
Calcium, mg	153.82 ±17.68	15.4
Magnesium, mg	39.44 ±5.62	9.4
Phosphorus, mg	144.34 ±8.48	18.0
Micronutrients		
Iron, mg	0.733 ±0.098	7.3/4.1**
Zinc, mg	1.012 ±0.154	8.4

Note: *RDA – recommended daily requirement by over 18 of age by MR 2.3.1.0253-21 (Norms of physiological requirements in energy and food substances for different population groups of the Russian Federation); ** values RDA for men/women.

Following TR CU 022/2011 **[52]**, the developed chopped meat and vegetable semi-finished products are a source of micro- and macroelements and vitamins, namely calcium and phosphorus in their recommended ratio and vitamin A. They also contain most B vitamins, vitamin C, fat-soluble vitamins D and E, macronutrients potassium and magnesium, and trace elements iron and zinc.

Including dry milk molasses with lactulose "LactuVet-1" in the formulation of the developed meat products made it possible to obtain products with a more pronounced aroma, juiciness, and uniform colour shade (Figure 2).

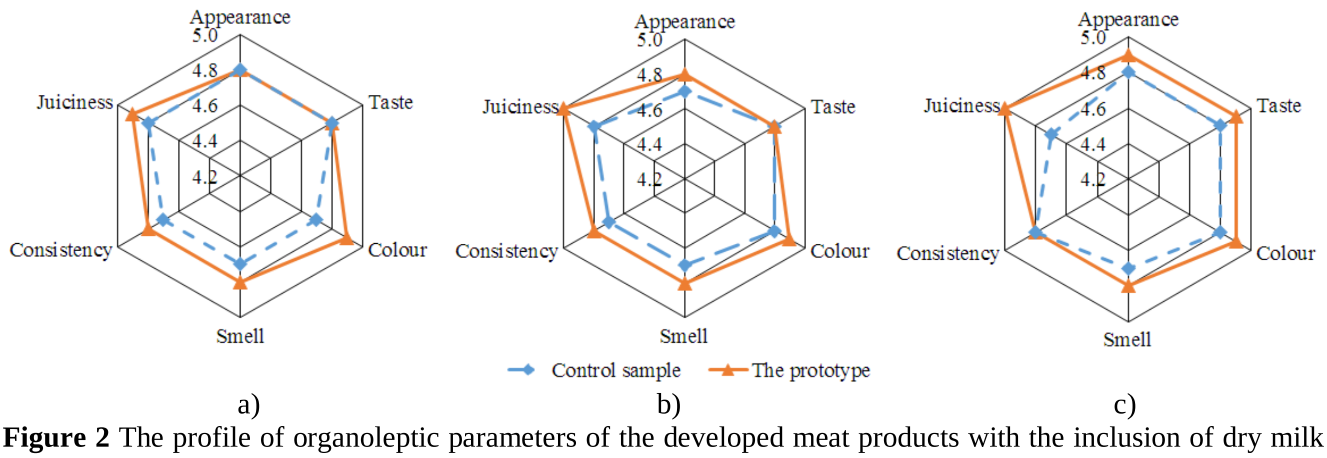

Figure 2 The profile of organoleptic parameters of the developed meat products with the inclusion of dry milk molasses with lactulose "LactuVet-1" in the formulation (the prototype) and without it (control sample): a) boiled sausage; b) liver pate; c) chopped semi-finished products.

The appearance of the developed meat and vegetable semi-finished products, boiled sausages, and liver paste is shown in Figure 3.

Figure 3 The appearance of the developed fortified meat products.

The use in formulations of fortified meat products of milk molasses with lactulose "LactuVet-1" allowed for the increase of organoleptic characteristics and provided a pronounced health-preventive effect of finished products at a reduced cost. This effect is due to the presence of molasses of lactulose – prebiotic No. 1 in the world **[11]** and dry milk sugar – lactose **[54]**, as well as a complex of minerals. Dry milk molasses with lactulose as a functional ingredient has a low cost **[10]**. In addition, in the course of our research, it was noted that dry milk molasses with lactulose provides a reduction in thermal losses and an increase in the yield of finished products.

CONCLUSION

The results of the presented studies developed fortified cooked sausages, liver pate, and chopped meat and vegetable semi-finished products demonstrate the following advantages. Combination of meat, vegetable raw materials, and functional ingredients, including dry milk molasses with lactulose "LactuVet-1", allowed to provide finished meat products with high-grade protein, vitamins, micro-, macroelements to achieve prebiotic action, high organoleptic characteristics and reduce the cost price, which is also important for young people. In the developed meat products, 100 g contains 20-35.5% of the minimum recommended daily intake of the lactulose prebiotic. The products are balanced in essential amino acids. They have consistently high nutritional and biological value while being enriched in a natural form of calcium and other minerals that are easily available for assimilation by the body. The values of the general criterion for the desirability of the amino acid composition of protein for the proposed meat products range from 0.67 to 0.96 units. They are rated “good” and “excellent” on the Harrington Desirability Scale. The biological value of protein is 87.7% for liver pate, 92.8% for boiled sausages, and 99.7% for chopped semi-finished products. Cooked sausage products developed by TR CU 022/2011 are a source of vitamin A, calcium, phosphorus, and selenium and contain about 45 mcg of iodine per 100 g product. Liver pate has a high content of vitamins A, B2, and B12, the amount of which in 100 g of product is approximately 3.47 mg, 0.78 mg, and 19.94 mcg, respectively. Pate is a source of iron, calcium, phosphorus, and vitamins E, B3 and B5. Chopped meat and vegetable semi-finished products contain most B vitamins, vitamin C, fat-soluble vitamins D and E, macroelements potassium and magnesium, and microelements iron and zinc. Semi-finished products are a source of calcium, phosphorus, and vitamin A, which in 100 g of product is approximately 153.82 mg, 144.34 mg, and 0.14 mg, respectively.

Introducing the developed meat products into the diet of the target youth group of consumers aims to reduce the imbalance of the main nutrients identified during the study and analysis of their nutritional status. It is recommended that clinical studies be conducted with confirmation by an additional array of experimental data.

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Funds:

The work was carried out with the financial support of the Ministry of Science and Higher Education of the Russian Federation within the framework of the implementation of a comprehensive project for the creation of high-tech production on the topic: "Creation of Russia's first high-tech production of prebiotic lactulose and functional dairy ingredients for import substitution in medicine, veterinary medicine, infant nutrition, production of therapeutic and preventive products for humans and animals" (Agreement on granting a subsidy from the federal budget for the development of cooperation between a state scientific institution and an organization of the real sector of the economy for the purpose of implementing a complex project for the creation of high-tech production No. 075-11-2022-021 dated 04/07/2022) within the framework of the Resolution of the Government of the Russian Federation dated 9 April 2010 No. 218 on the basis of the FSAEI HE "North-Caucasus Federal University".

Acknowledgments: -

Conflict of Interest:

No potential conflict of interest was reported by the author(s).

Ethical Statement:

This article does not contain any studies that would require an ethical statement.

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