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Development of technology for plant-based minced semi-finished products

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Abstract. A healthy diet is the key to longevity, increasing the body's resistance to adverse environmental influences, and is a prerequisite for quality of life. One of the problems that humanity must solve today is the search for non-traditional protein sources and their popularisation in the food market as a healthy alternative to meat protein, which is the most popular. Nowadays, vegetarianism is the most widespread system of health-improving nutrition. According to this system, meat products (pork, beef) are replaced from the daily diet and other sources of amino acids take their place. The relevance of the study is related to the need to develop minced semi-finished products suited for consumption by a wide range of consumers, including those who adhere to vegetarian and vegan diets. The main goal of the study was to achieve the nutritional value of the protein component of minced meat compared to beef-based minced meat. The following research methods were used to solve these tasks: the organoleptic assessment considered: appearance, colour, cutaway view, smell, taste; moisture content – by drying the sample to a constant weight; fat content – by Soxhlet method; protein content – by Kjeldahl method; amino acid composition – by liquid chromatography, fatty acid composition – by gas-liquid chromatography. The main ingredient with protein content in minced meat is protein-wheat texture, which contains a balanced set of amino acids. The study of the amino acid composition of meatless minced semi-finished products has shown that this product is a valuable source of all essential amino acids. Cutlets are characterized by a significant content of valine, methionine, and phenylalanine. The finished product meets the requirements of the current regulatory documentation and does not pose a microbiological danger to the consumer. Therefore, the development of a new semi-finished product technology, which is a meatless minced meat composition that meets the requirements of a healthy diet in terms of protein and fat composition, is one of the ways to solve the problem of introducing food products recommended for vegetarians

Keywords: minced meat; protein; soy-wheat texturate; amino acids; hydration; fatty acids; healthy eating

Introduction

Nutrition is one of the most important environmental factors that directly affect the human body throughout its life. Biological components of food, which in the process of metabolism turn into structural and functional elements of the body's cells, ensure their physiological and psychological performance, adaptability, and immune status, and determine the state of human health, life expectancy, and social and personal activities. Therefore, the defining feature of the current stage of social development is that the problem of protecting the health of the population and extending the life expectancy of each person is no longer at the center of

attention only in biology and medicine, but also significant progress has been made beyond these sciences (Nazarenko & Ustymenko, 2023).

The human condition, as defined by the World Health Organisation, is “a state of complete physical, mental, and social well-being”, and not just the absence of diseases (Li *et al.*, 2018). Despite this, the foundations of the healthcare system are focused on the organization of a healthy lifestyle, the main advantages of which are considered to be (Bal-Prylypko *et al.*, 2022):

- longevity;
- high physical performance;
- increased mental and business activity.

- resistance to the occurrence and development of diseases;

- prevention and resistance to obesity.

Each of these factors allows for increasing life expectancy by about two years. Vegetable raw materials are of great importance in human nutrition as a dietary product rich in vitamins, contributing to normal metabolism. When it comes to finding healthy food, most people today are not content with official or traditional views but constantly find their way. This has led to the emergence of many alternative nutrition systems (Ivaniuta *et al.*, 2021). Among them, the most important is a rational diet, depending on age, gender, level of physical activity, and intake of all the necessary substances with food, the number of which is close to 70 (Holembovskaya *et al.*, 2021). Of these, carbohydrates, fats, and proteins play an important role in regulating the body's metabolic and energy processes, the sufficiency and usefulness of which determine the health status of the average consumer by 68-74% (Bal-Prylypko *et al.*, 2022).

Among the main types of healthy eating, the most common are vegetarianism, separate meals, and raw food. Today, the vegetarian menu is also gaining popularity in restaurant establishments (Tolok, 2018). Various aspects of the development of the food system – vegetarianism and the activities of vegetarian institutions are covered by such researchers as: G.A. Tolok (2018), M.V. Buzhanska (2022), and M.V. Skobenko *et al.* (2022). Consideration of the papers by the above-mentioned researchers allows for taking a meaningful approach to the analysis of the scientific task set, identifying issues that remain relevant.

In the next 10 years, the market for plant-based alternatives will occupy 10% of the global meat market. The number of Ukrainians who gave up meat, the most successful young people, has reached 2 million and continues to

grow (Bal-Prylypko *et al.*, 2022). Conscious consumers take a thoughtful approach to nutrition and understand the impact of their choices on the health of both themselves and the planet. The absence of allergens in food, “clean labels”, and “eco-friendly products” are not all that concern the modern consumer. Being picky means not only choosing products with a healthier list of ingredients, but also paying attention to packaging, production methods, consumption, processing, and delivery methods (Onwezen, 2021). Therefore, the main goal in developing the technology of plant-based minced semi-finished products was to achieve the nutritional use of the protein component of plant-based minced meat in comparison with beef-based products.

Literature Review

Considering the arguments in favor of limiting meat consumption and a significant increase in the cost and shortage of animal products, the task arose to develop recipes for meatless minced cutlets. The main task was to rationally plan the complete replacement of animal protein with vegetable protein by including it in the composition of products that would contain a set of amino acids close to the characteristics of meat (Ivaniuta *et al.*, 2021). The problem statement, in addition to solving the issue of reducing environmental pressure on the environment while reducing the caloric content of the product, is conditioned by the need to expand the range of consumers to include people who adhere to vegetarian nutrition principles.

Among the ingredients of food products, proteins play a decisive role in the normalization of plastic and partial energy processes (Bal-Prylypko *et al.*, 2023). The body's need for protein depends on the age of the individual. The recommended amount of protein, depending on age, is shown in Table 1.

Table 1. Protein requirements of the body

Consumer category	The recommended amount of protein, grams per day	
	total	including animal
Children under 1-year-old	up to 3	up to 2.5
Children 1-5 years old	53-65	33-37
Children 6-10 years old	72-78	36-39
Children 11-17 years old	83-104	42-52
Adult men	102-107	53-59
Adult women	78-84	43-46

Source: (Ihnatenko, 2019)

In recent years, researchers have proven the expediency of fulfilling the protein deficiency in the human diet by using vegetable protein. The majority of published studies (Bal-Prylypko *et al.*, 2022) state that the predominance of animal protein in the diet is associated with the proximity of its amino acid composition to the physiological needs of humans, and meat, eggs, and poultry are considered the best sources of its production. At the same time, one of the main conditions for a healthy diet is considered to be maintaining a ratio close to 1:2 by weight in the protein component of the content of essential and non-essential amino acids.

However, the use of raw meat in consumer goods has many disadvantages. First of all, a large group of supporters of vegetarianism remains outside the consumer group. Moreover, significant problems should include the ingress of waste products into the natural environment when raising domestic animals. According to N.V. Novhorodska *et al.*, (2021) “a farm with 2,500 animals that give milk creates as much waste as a city with a population of 411 thousand people.” In addition, the share of carbon dioxide generated in the process of growing fodder crops, harvesting, processing, and transportation of feed and meat made from them reaches 9% on a global scale. Moreover, according to the UN, raising and keeping domestic animals is accompanied by the generation of up to 18% of global greenhouse gas emissions –

methane, ammonia, and nitrogen monoxide, which is significantly more than land, sea, and air transport, which accounts for only 13% of their total amount (Eveleva *et al.*, 2019).

No less important arguments in favor of finding alternative sources of food protein production are that pastures used by humanity in raising animals occupy up to a third of the areas suitable for farming, and the amount of water consumed by industrial technologies to obtain, for example, 1 kilogram of beef requires about 15 thousand liters of water. Less water-intensive is the production of other types of meat: 6 thousand liters for pork, 4,300 liters for chicken, while the production of, for example, 1 kilogram of soy requires 2 thousand liters, wheat – 1 thousand, potatoes – 100 liters (Shugang *et al.*, 2017).

Materials and Methods

The research was conducted to complete the tasks set according to the established relevant standard methods: the organoleptic assessment considered: appearance, colour, cutaway view, smell, and taste according to DSTU 4437:2005 (2007) “Semi-finished meat and meat-vegetable minced products”; moisture content – by drying according to DSTU ISO 1442:2005 (2007) “Meat and meat products. Method for determining the moisture content”; the number of proteins was determined according to GOST 25011-2017 (2018) “Meat and meat products. Methods of protein determination”;

the amount of fat was determined by DSTU 8380:2015 (2017) “Meat and meat products. Method for measuring the mass fraction of fat”; the amino acid composition was determined by liquid chromatography using an amino acid analyzer “BIOTRONIK” (Germany); the fatty acid composition was determined by gas-liquid chromatography using an Automated Gas Chromatograph “Kupol-55”; microbiological indicators of finished products were determined by DSTU 4437: 2005 (2007) “Semi-finished meat and meat-vegetable minced products”, the total caloric value was calculated from the sum of values for 100 g of product, based on the following ratios: 1 g of protein – 4 kcal (16.7 kJ), 1 g of fat – 9 kcal (37.7 kJ), 1 g of carbohydrates – 3.75 kcal (15.7 kJ).

The ingredients used for the preparation of semi-finished products required special preparation methods. The main condition was to achieve uniformity of emulsions, the prerequisite for which is the transfer of solid ingredients (soy-wheat texture, methylcellulose) to the state of an emulsion. This is the

fundamental difference between the preparation of plant raw materials, which, unlike meat raw materials, require pre-hydration. This action, as well as work on preparing for the use of other ingredients in minced meat, was performed as follows.

Soy-wheat texture, which contained 10% adsorbed water, was mixed with three parts cooled to 4°C water and at a speed of 60 rotations of the frame agitator per minute, stirred for 20 minutes until uniformity. Methylcellulose was used as an additive designed to bind fat and prevent the delamination of minced meat mixtures. To transfer it to the emulsion state, powdered methylcellulose was mixed with 2% sunflower oil, and a water-ice mixture was added to the system and mixed at a speed of 60 rotations of the frame agitator per minute until uniformity. The amount of water phase required for the mixture to achieve plasticity was varied to determine the optimal amount of water fraction. The ratio of components and properties of water-oil emulsions of methylcellulose are shown in Table 2.

Table 2. Component ratios and properties of methylcellulose water-oil emulsions

No.	Component ratio			State of the emulsion after homogenization	Emulsion consistency	Condition of hydrated fibers
	Methylcellulose	Sunflower oil	Water-ice mixture			
1	1	2	7	Rubber-like condition, high elasticity	High-density difficult mixing	Partial hydration, the presence of a solid phase
2	1	2	15	Dense structure, shape retention	Condition is similar to sour cream	Full hydration uniform condition
3	1	2	25	Stratification of the emulsion, the release of free moisture	Spreading of the emulsion without preserving its shape	Full hydration, availability of free moisture

Based on the comparison of the state of the emulsions, a choice was made in favor of experiment No. 2, because the selected ratio of components provided a dense consistency

and preserved the shape. The prepared ingredients were mixed in a cutter with the remaining components of the minced meat mixture in an arbitrary sequence. In the period from

February 2021 to February 2022, following the requirements of DSTU 4437:2005 (2007), many tastings of cutlets based on plant raw materials were conducted among vegans aged 18 to 53 years, as well as among consumers who adhere to a traditional diet, and about 150 reviews were processed. Studies were also conducted among the meat-consuming population, who tasted cutlets based on meat and plant raw materials. Indicators of appearance, cutaway view, color, taste, aroma, consistency, and juiciness were evaluated on a five-point scale. Works with human participants following the principles set out in the Helsinki Declaration

The organoleptic assessment was carried out in 3 stages:

1. Tasting of plant-based semi-finished products in their pure form (simple heat treatment, without sauces and side dishes)
2. Tasting of plant-based semi-finished products in ready meals (burgers).
3. Tasting of plant-based semi-finished products as a filling for complex dishes, with the addition of other flavor components (ravioli, dumplings).

Results and Discussion

Comparative studies of beef proteins and soy and wheat textures to a certain extent refute the myth of the essential nature of animal protein and show close similarity in the amino acid

composition of all three sources, especially in terms of obtaining the necessary complex of amino acids with plant-based meat substitutes: industrial batches of both soy and wheat texture according to their content, including those that the body is not able to synthesize, can be considered as its healthy replacement in minced meat mixtures. Therefore, it was concluded that it is advisable to develop recipes for minced plant-based products as an alternative to minced meat containing animal protein.

The second most protein-rich component of minced cutlet mixes is fat. Sunflower oil is traditionally used in this capacity in Ukrainian national cuisine, provided that animal fat is avoided. However, its chemical composition does not meet the existing dietary guidelines for the ratio of omega-6 and omega-3 fatty acids. Their mass fractions in oil are $48.3 \div 74.0\%$ and 0.3% , respectively (Table 3), while in the optimum their ratio is in the range from 1:2 to 1:4. The consequences of this discrepancy can be an increase in blood viscosity and a tendency for excessive clotting, which can lead to blood clots and high blood pressure. In part, this ratio may be close to the recommended dosage reduction of sunflower oil in minced meat and the introduction of coconut oil in it instead, the composition of which is shown in Table 3 in comparison with the composition of sunflower oil.

Table 3. The fatty acid content in sunflower and coconut oils, %

Fatty acid	Oilseed crop	
	Sunflower	Coconut
Lauric (C12)	up to 0.1	43.0-51.0
Myristic (C14)	up to 0.2	16.0-21.0
Palmitic (C16)	5.0-7.6	7.5-10.0
Palmitoleic (C16)	up to 0.3	0.2-1.5
Stearic (C18)	2.7-6.5	2.5-4.0
Oleic – ω -9 (C18)	14.0-39.4	5.0-10.0
Linoleic – ω -6 (C18)	48.3-74.0	1.0-2.5
Linolenic – ω -3 (C18)	up to 0.3	up to 0.5

Table 3. Continued

Fatty acid	Oilseed crop	
	Sunflower	Coconut
Arachidic (C20)	0.1-0.5	up to 0.5
Gadoleic (C20)	up to 0.3	up to 0.5
Behenic (C22)	0.3-1.5	up to 0.5
Erucic (C22)	up to 0.3	up to 0.5
Docosadienoic (C22)	up to 0.3	n/a
Lignoceric (C24)	up to 0.5	up to 0.5

An additional argument in its favor is that coconut oil is rich in myristic acid, which is extremely important for strengthening memory, which is practically absent in sunflower and olive oils widely used in such recipes (Wu *et al.*, 2018).

Based on the benefits of replacing the meat component with vegetable textures, given the traditional set of additives to minced meat and the

norms of their use, a recipe for a chopped minced product that does not contain a meat component was developed (experiment). Dietary minced meat based on the use of beef that meets the requirements of the national standard DSTU 4437-2005 (2007) was selected as a control comparison sample. Recipes for minced meat (control and experimental samples) are presented in Table 4.

Table 4. Recipes for minced cutlets based on meat and plant raw materials

Recipe component	Mass fraction of the ingredient, %	
	Control	Experimental
Water	23.8	62.3
Beef cutlet meat	25.1	-
Sausage ridge fat	30.2	-
Soy-wheat texturate	-	21.0
Wheat flour bread	11.1	-
Breadcrumbs	4.0	-
Hydrolyzed vegetable protein	-	0.7
Dry potato or wheat fiber	2.0	-
Yeast extract	-	0.7
Table salt	1.2	0.7
Beetroot juice	-	1.0
Chopped onion	3.5	-
Coconut oil	-	6.3
Methylcellulose	-	2.0
Sunflower oil	-	5.0
Vegan flavoring AlmaMit C25/11	-	0.3
Ground black or white pepper	0.1	-

Nevertheless, the main criterion for the quality of minced meat in the proposed recipe is the usefulness of the amino acid composition of the protein component. The corresponding calculation was made because wheat

added to the control minced meat with the meat component contains about 12% protein in total, and its content in the added bread does not exceed 50 %. The calculation results are shown in Table 5.

Table 5. Amino acid composition of experimental and control minced meat products, g/100 g

Amino acid	Experimental	Control
Essential amino acids		
Valine	1.5	1.4
Isoleucine	1.1	1.1
Leucine	1.8	2.1
Lysine	0.9	2.1
Methionine	0.5	0.2
Threonine	0.7	1.2
Tryptophan	0.2	0.3
Phenylalanine	1.4	1.2
<i>Total essential amino acids</i>	<i>8.1</i>	<i>9.6</i>
Non-essential amino acids		
Alanin	0.9	1.5
Arginine	1.6	1.5
Aspartic acid	1.7	2.5
Histidine	1.0	1.0
Glycine	1.2	1.3
Glutamic acid	4.5	4.6
Proline	1.6	1.2
Serine	1.1	1.1
Tyrosine	0.8	1.0
Cystine	0.3	0.3
<i>Total non-essential amino acids</i>	<i>14.7</i>	<i>16.0</i>
<i>The total content of amino acids in the composition</i>	<i>22.8</i>	<i>25.6</i>

To calculate the caloric content of the product, the values of the corresponding characteristics of proteins at 16.75 kJ/g, fats at 37.5 kJ/g, and carbohydrates at 16.5 kJ/g

were used. The results of determining the chemical composition of samples of plant-based “meat” semi-finished products are shown in Table 6.

Table 6. Chemical composition of control and experimental samples of minced meat cutlets ($n=3$, $p \geq 0.95$)

Mass fraction of the component, %	Control	Experimental
Protein	17±0.1	16.7±0.1
Fat	10±0.04	9.78±0.04
Carbohydrates	0.7±0.03	5.35±0.03
Moisture	68.1±0.3	64.6±0.3
Table salt	1.3±0.1	1.52±0.1
Fibre	0	1.15
Caloric value, kJ	560 (133.8 kcal)	615 (146.6 kcal)

A comparative analysis of the chemical composition of semi-finished beef products

produced using conventional technology and with plant raw materials shows that plant-based

products are characterized by a high content of fats and carbohydrates and an insignificant decrease in protein content. Moreover, plant-based products are distinguished by the presence of fiber in their composition, which significantly improves intestinal function. To determine the compliance of the developed

composition with the requirements of sanitary and epidemiological safety in comparison with the control following the indicators of the national standard DSTU 4437-2005 (2007), the product was tested during the guaranteed shelf life (10 days from the date of manufacture). The test results are presented in Table 7.

Table 7. Results of determination of the level of bacteriological contamination of minced meat products of experimental and control composition

Product	Indicator of bacteriological contamination			
	Coliform bacteria in 0.1 g	<i>L.monocytogenes</i> in 25 g	<i>S.aureus</i> in 1 g	Pathogenic, incl. salmonella in 1 g
Control	Not Found	Not Found	Not Found	Not Found
Experimental	Not Found	Not Found	Not Found	Not Found

Analysis of the data in Table 7 shows that the microbiological indicators of the finished product met the requirements of the current

regulatory documentation on microbiological safety.

The data obtained are shown in Figure 1.

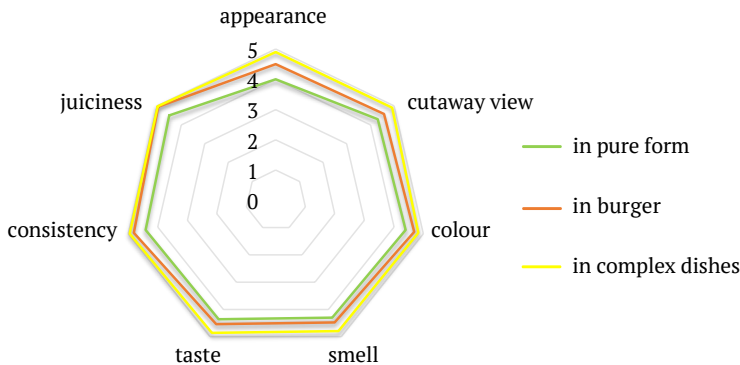


Figure 1. Results of evaluation of organoleptic parameters of minced semi-finished products of experimental and control composition

The results of the sensory analysis showed that plant-based semi-finished products such as minced meat and filling have the highest overall score in all indicators, based on which it was concluded that meatless minced semi-finished products on a plant basis can be recommended for general consumption both due to their nutritional value and compliance with the

established taste preferences of a wide range of consumers, including those who adhere to the norms of vegetarianism.

Conclusions

The properties of soy protein allow it to be actively used in the meat processing industry of the food industry. As for the production of

minced semi-finished products of plant origin, they are indispensable in the diet of people who do not consume animal proteins.

According to the study results, it was determined that the composition of the developed minced plant-based product is practically equivalent to the composition of minced meat from the standpoint of providing the body with proteins and meets the standards of healthy nutrition. It is shown that the developed meatless minced meat composition is close to the composition of traditional ground beef in terms of protein component composition and can be recommended for use in traditional diets. The finished product using the developed technology almost does not differ in consumer qualities from the meat product using conventional technology. The study of the amino acid composition of meatless minced semi-finished products has shown that this product is a valuable source of all essential amino acids. Cutlets are characterized by a significant content of valine, methionine, and phenylalanine.

Analysis of the chemical composition of semi-finished products made from beef using conventional technology and based on plant raw materials proves that plant-based products are characterized by a high content

of fats and carbohydrates and an insignificant decrease in protein content. Moreover, plant-based products are distinguished by the presence of fiber in their composition, which significantly improves intestinal function. The tasting committee noted that the consistency of the product is very similar to meat, and the cooking method allows for maintaining a traditional food culture. Tasting by meat eaters showed that there were no significant changes in the organoleptic properties of the product and people who consume meat will not feel uncomfortable when consuming a product that does not contain meat.

The developed technology of mincing semi-finished products will significantly expand the range of products for people who adhere to vegetarian and vegan standards of phytonutrients, which will somewhat mitigate the current problems of healthy eating. The positive research findings indicate that this technology should be further studied and requires further development.

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None.

Conflict of Interest

None.

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Розробка технології січених напівфабрикатів на рослинній основі

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Анотація. Здорове харчування є запорукою довголіття, підвищення стійкості організму до несприятливих впливів довкілля, є умовою якості життя. Однією з проблем, яку сьогодні мусить вирішувати людство, є пошук нетрадиційних джерел білка, а також їх популяризації на продуктовому ринку як здорової альтернативи м'ясному білку, який користується найбільшою популярністю. На сьогодні вегетаріанство є найбільш широко розповсюдженою системою оздоровчого харчування. За цією системою з повсякденного раціону витісняють м'ясні продукти (свинину, яловичину) і на місце їм приходять інші джерела амінокислот.

Актуальність роботи пов'язана з необхідністю розробки фаршевих напівфабрикатів дозволених до вживання широким колом споживачів, включаючи осіб, які дотримуються вегетаріанських та веганських норм харчування. Основною метою досліджень було досягнення харчової повноцінності білкового компоненту фаршу у порівнянні з фаршами на основі яловичини. Для вирішення поставлених завдань використовували такі методи досліджень: при органолептичній оцінці враховувалися: зовнішній вигляд, колір, вид на розрізі, запах, смак; вміст вологи – методом висушування зразка до постійної маси; вміст жиру – методом Сокслета; визначення вмісту білка – методом К'ельдаля; амінокислотний склад визначали методом рідинної хроматографії, жирнокислотний склад визначали методом газорідинної хроматографії. Основним інгредієнтом із вмістом білка у фарші використаний білково-пшеничний текстурат, який містить збалансований набір амінокислот. Вивчення амінокислотного складу безм'ясних подрібнених напівфабрикатів показало, що цей продукт є цінним джерелом усіх незамінних амінокислот. Котлети характеризуються значним вмістом валіну, метіоніну й фенілаланіну. Готовий продукт відповідає вимогам чинної нормативної документації та не становить мікробіологічної небезпеки для споживача. Тому розробка технології нового напівфабрикату, яка являє собою безм'ясну фаршеву композицію, за складом білкового та жирового компоненту відповідає вимогам здорового харчування, є одним із шляхів вирішення проблеми впровадження харчових продуктів, які рекомендовані для вегетаріанців

Ключові слова: фарш; білок; соєво-пшеничний текстурат; амінокислоти; гідратація; жирні кислоти; здорове харчування