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MODELING THE TECHNOLOGY OF COOKED MINCED MEAT PRODUCTS USING ALTERNATIVE PROTEINS

In the current climate, ensuring Ukrainian military personnel receive comprehensive nutrition with high biological value is of paramount strategic importance. Conventional meat products often fail to meet the demands of field nutrition and the standards of modern healthy diets, particularly concerning the increasing need for protein. Employing alternative protein sources and optimizing the formulation of meat products presents a viable avenue for addressing this challenge. This study details the development of an innovative formulation for "Military" cooked sausage, incorporating Helix pomatia snails and protein isolate derived from pumpkin seed meal. This approach enhances the nutritional value of the product while promoting the sustainable utilization of food production byproducts. Snail meat offers a valuable source of complete protein, vitamins, and micronutrients, coupled with a low-fat content. Pumpkin seed protein isolate serves as a concentrated source of plant-based protein, abundant in essential amino acids. Through mathematical modeling, an optimal ratio of 18 g of snail meat and 4.5 g of pumpkin seed protein isolate per 100 g of sausage was established. This ratio ensures superior organoleptic and physicochemical properties. Organoleptic assessment confirmed the excellent taste profile of the "Military" sausage. Physicochemical analyses revealed that the newly developed formulation improves the functional and technological characteristics of the sausage meat. The water-holding capacity (WHC) of the "Military" sausage is 74.2%, surpassing the control by 0.8%. Similarly, the fat-holding capacity (FHC) exceeds the control by 2.8%, reaching 73.8%. The inclusion of pumpkin seed protein isolate enhances the stability and consistency of the meat matrix. The findings of this research provide a scientific basis for the production technology of the "Military" cooked sausage. The process involves incorporating Helix pomatia snails and fortifying the product with protein isolate from pumpkin seed meal. This innovation will contribute to a broader range of meat products with enhanced nutritional profiles for military personnel in Ukraine. Future research will focus on evaluating safety parameters, shelf-life stability, and the potential integration of other alternative protein sources. This development represents a significant advancement in providing the Ukrainian military with high-quality food products, ultimately contributing to their operational effectiveness and overall well-being.

Keywords: *mathematical modeling, recipe optimization, food waste, alternative proteins, cooked sausages, military rations, healthy diet.*

Statement of the problem and its relevance. The transformation of dietary habits, driven by modern lifestyles and decreased physical activity, leads to deficiencies in essential nutrients, micro- and macronutrients in the diets of various population groups. A promising solution to this problem is the consumption of fortified meat products with a multi-component composition [1].

An innovative approach to meat product manufacturing involves modifying traditional recipes by incorporating high-quality additional ingredients and bioactive additives. This allows for the optimization of nutritional value, sensory characteristics, texture, and enrichment of products with essential nutrients [2].

Essential amino acids, vital for maintaining the physiological balance of the body, can be obtained from non-traditional sources such as land snail meat and pumpkin seed protein isolate [3]. Particular attention should be paid to providing the body with essential amino acids, which play a key role in regulating metabolism and are structural components of hormones and enzymes. An effective method for enriching meat products with essential amino acids is the introduction of land snail meat and pumpkin seed meal protein isolate into the composition of cooked sausage mince [4].

Snail meat is rich in protein (10–15%), contains essential amino acids, minerals (iron, calcium, magnesium), vitamins (B12, E), and polyunsaturated fatty acids, and their cultivation is environmentally friendly and economically viable [5]. Scientific research has confirmed the effectiveness of the technology for obtaining protein isolate from pumpkin seed meal, which is characterized by a high content of complete protein with a balanced amino acid composition [6].

Studies have shown that pumpkin seed meal protein isolate has significant nutritional value and pronounced emulsifying properties, making it a promising component for creating stable multi-component systems [7]. Pumpkin seed meal protein isolate has high nutritional value, functional properties (water-holding and fat-holding capacity), and is also an accessible and relatively inexpensive ingredient [8]. The introduction of pumpkin seed meal protein isolate into the composition of food products does not impair their sensory characteristics, but rather contributes to improving the texture and consistency of meat mince [9].

Analysis of recent research and publications. Meat products, particularly cooked sausages, provide the human body with essential nutrients and are convenient to consume under various temperature conditions (Shin D.M. et al. [10]). Cooked sausage mince, which is an emulsified system, forms its quality characteristics depending on the functional and technological properties of its components (Gao D. et al. [11]).

In recent years, there has been a trend in sausage production technology towards replacing traditional meat raw materials with alternative types, such as vegetable proteins (soy), mechanically separated meat, block-imported meat, and meat with a high content of fat and connective tissue (Gao D. et al. [12]). The use of such raw materials can lead to a deterioration in the amino acid and fatty acid composition,

as well as a decrease in the content of minerals in finished sausage products, which negatively affects the nutritional value of the product and can cause an imbalance in consumer nutrition (Helikh A. et al. [13]).

Analysis of the nutritional status of the Ukrainian population indicates insufficient consumption of complete animal proteins, an imbalance in the lipid composition of the diet, and a deficiency of certain trace elements (Sebranek J.G. & Bacus J.N. [14]). According to research, the deficit in the consumption of complete protein in Ukraine in 2022 was 45.5% for the northern regions and 34% for the southern regions (Golovko N. et al. [15]). Low levels of selenium in the body can be associated with its insufficient content in soil, water, and food, which is typical for regions with technogenic pollution. In such conditions, it is important to expand the use of alternative protein sources, such as freshwater aquatic organisms (Vasilenko O. et al. [16]).

The development of new types of meat products that meet the principles of healthy eating is a relevant trend in the food industry. One of the promising approaches is the creation of meat products with a multi-component composition, enriched with biologically valuable components such as land snail meat and pumpkin seed protein isolate (Gøtterup J. et al. [17]). These ingredients make it possible to increase the nutritional value of meat products and enrich them with essential amino acids, minerals, and biologically active components (Löfblom J. et al. [18]).

The use of land snail meat in meat product recipes makes it possible not only to diversify sources of raw materials but also to increase the biological value of the finished product. Snail meat is characterized by a high content of easily digestible protein, the presence of essential amino acids, minerals, and biologically active compounds (Jin S.-K. et al. [19]).

The study of the physicochemical, functional, technological, and nutritional properties of land snail meat and vegetable protein isolates is the subject of many scientific papers. Scientists are actively exploring the possibilities of using these ingredients in the production of meat products to increase their nutritional and biological value (Bahadoran Z. et al. [20]). Despite the widespread consumption of sausages, their recipes often do not meet the requirements of a balanced diet due to the high content of fat, salt, and artificial additives. Therefore, the creation of new types of sausages with a multi-component composition, enriched with physiologically functional ingredients, is an important area of scientific research in the field of food technology (Chhikara N. et al. [21]).

In Ukraine, cooked sausage occupies a significant share of the meat product market. According to market analysis data, about 29% of all sausage products are cooked sausages, which are preferred by 80% of consumers. At the same time, 40% of the population consumes cooked sausage 2–3 times a week (Liu Y. et al. [22]).

The development and implementation of biologically complete meat products with a multi-component composition is an urgent task within the framework of the concept of a balanced diet. Such products have an advantage due to the possibility of introducing various ingredients into their composition, which allows optimizing their nutritional value in accordance with the physiological needs of the body (Liu Y. et al. [23]). One of the disadvantages of traditional sausage products is the low content of essential trace elements and an imbalance in the amino acid composition. Losses of minerals occur at various stages of the technological process, particularly during mincing and heat treatment. This reduces the nutritional value of the finished product and limits its ability to meet the body's needs for micronutrients (Milana M. et al. [24]).

The introduction of *Helix pomatia* meat and pumpkin seed meal protein isolate into the recipe of cooked sausages contributes to the enrichment of the product with biologically valuable components and an increase in its nutritional value. The development of such sausage products is a promising direction for creating functional food products that would satisfy the needs of consumers for a balanced diet without significant changes in their eating habits (Helikh A. et al. [25]).

Objectives of the article. The purpose of the article is to substantiate the innovative technology of cooked sausage "Military" with the introduction of *Helix pomatia* meat and pumpkin seed meal protein isolate into the recipe.

Research Methods. Standard organoleptic and structural-mechanical methods, methods of experiment planning and mathematical processing of experimental data using modern computer programs were employed in this study.

Summary of the main research material. Meat products occupy an important place in human nutrition, providing the body with essential nutrients. Modern trends in the food industry are aimed at developing multi-component meat products, which are characterized by an enriched chemical composition, increased nutritional and biological value, as well as a balanced content of amino acids and minerals.

Sausage products are food products made from minced meat with the addition of fat, offal, salt, and spices, which undergo heat treatment or fermentation to achieve culinary readiness. The meat raw materials used in the production of sausages are a source of complete animal protein, lipids, vitamins, and minerals.

In the process of developing recipes for multi-component meat sausages with the addition of land snail meat and pumpkin seed meal protein isolate, an important step is the selection of the optimal ratio of main and additional ingredients. In particular, it is necessary to determine the amount of pumpkin seed meal protein isolate that would provide the best organoleptic and physicochemical indicators of the finished product.

When choosing a recipe for cooked sausage, the requirements of the current DSTU 4436:2005 were taken into account, and the recipes of existing sausages, in particular "Likarska", were analyzed. To optimize the amount of pumpkin seed meal protein isolate and land snail meat in the recipe of cooked sausage, a mathematical modeling method was used using an orthogonal central composite design of the second order for two factors. The amount of *Helix pomatia* meat (Kp) and pumpkin seed meal protein isolate (Kd) introduced were chosen as factors. The optimization of the formulation also considered its alignment with NATO military

nutrition standards [26]. The range of variation of factors and the interval of their variation are given in Table 1.

To optimize the cooked sausage recipe, two key parameters were analyzed: the organoleptic evaluation (O), which reflects the set of sensory characteristics of the product, and the water holding capacity (WHC) – an important indicator of the quality of the sausage emulsion.

"Ideal" values of private responses were used as optimization criteria: 27 points for organoleptic evaluation and 80% for water holding capacity. Based on these values, generalized optimization parameters (y) were calculated, which allow us to assess the combined effect of the studied factors on product quality.

To conduct an experiment on recipe optimization, an orthogonal central composite design (OCCD) of the second order for two factors was used. The experiment plan according to the OCCD matrix is presented in Table 2.

As a result of mathematical processing of the data, a mathematical model in coded form (1) was obtained:

$$y = 0{,}634567 - 0{,}0574532_{x1} + 0{,}002_{x}^{2} - \\ - 0{,}006785x1_{x}^{2} + 0{,}855789_{x1}^{2} + 0{,}034523_{x2}^{2} \quad (1)$$

When transitioning from the coded model to the natural expression, a response function was obtained that links the generalized optimization parameter with variable factors expressed in physical units of measurement (2):

$$y = 9087{,}76 - 9812{,}8K_{p} - 97{,}6139K_{d} - \\ - 0{,}7653K_{p}K_{d} + 8769{,}00K_{p}^{2} + 0{,}01298K_{d}^{2} \quad (2)$$

The calculated optimal values of the sought factors were: the amount of land snail meat – 18 g, and the amount of pumpkin seed protein isolate – 4.5 g per 100 g of cooked sausage "Military". The optimization of the recipe for "Military" cooked sausages was conducted based on the requirements for NATO military rations [26]. The optimized recipe is shown in Table 3.

Table 1 – Variable factors, their boundary values and variation intervals

Factor	Levels of variation			Interval of variation of factors, Δ_x
	-1	0	+1	
Amount of *Helix pomatia* meat (K_p) added, g	8.0	12.0	18.0	4.0
Amount of pumpkin seed protein isolate (K_d) added, g	1.5	0.5	4.5	1.5

Source: compiled by the author

Table 2 – Experiment plan and results of its implementation when determining the amounts of land snail meat and pumpkin seed protein isolate for cooked sausage "Military"

Experiment №	Experiment plan		Private responses		Private dimensionless responses		Generalized optimization parameter
	K_p, g	K_d, g	B, points	B_{whc}, %	S_{O2}	S_{Oh}	
1	18	1.5	23	79	0.0162	0.09	0.0292
2	8.7	1.5	21	67	0.0562	0.3456	0.1577
3	15.3	4.5	24	78	0.0786	0.04	0.0896
4	8.7	4.5	23	75	0.0493	0.3456	0.2938
5	18	0.5	26	87	0.0830	0.3456	0.1885
6	8.7	0.5	20	65	0.0534	0.0784	0.1719
7	10.0	1.5	25	71	0.0284	0.3456	0.0639
8	12.0	4.5	25	71	0.0050	0.0134	0.9324
9	10.0	0.5	24	70	0.0192	0.0204	0.0169

Source: compiled by the author

Table 3 – Recipe composition of cooked sausage "Military"

Ingredient name	Mass, kg per 100 kg of product
Main ingredients	
Beef, trimmed, 1st grade	30.0
Pork, trimmed	24.0
Landsnail meat	18.0
Pork backfat	22.0
Dried milk (or milk powder)	6.0
Potato starch	2.0
Auxiliary ingredients	
Pumpkin meal protein isolate	4.5
Water	12.3
Salt	2.0
Sugar	2.0
Black pepper	0.2

Source: compiled by the author

Organoleptic studies were conducted on the developed cooked sausage "Military" and a control sample of sausage made according to the standard recipe DSTU 4436:2005, based on the recipes of sausages such as "Likarska" and "Dytyacha Vershkova". Taste, smell, color, and consistency were evaluated. The profiles of the organoleptic evaluation of the cooked sausage "Military" are shown in Fig. 1.

Organoleptic evaluation of the cooked sausages, conducted through taste testing, demonstrated that the addition of pumpkin seed protein isolate at 4.5 g per 100 g of product had practically no effect on the sensory characteristics of the final product. However, the use of land snail meat in the sausage recipe contributed to the formation of unique flavor qualities, due to its specific chemical composition and interaction with other components of the sausage emulsion. It is important to note that the experimental sausage sample containing 18 g of snail meat per 100 g did not exhibit any off-flavors or odors.

Investigation of the functional and technological properties of land snail meat revealed that the minced muscle tissue has a liquid consistency and contains a significant amount of free water, which can complicate its technological processing. Mechanical action on the snail muscle tissue (grinding, pressing, cutting) results in the release of up to 30% tissue juice, rich in extractive substances.

However, the high content of free water in the minced snail meat can be utilized as an advantage in the technology of cooked sausage production. This allows for the elimination of additional liquid (water, broth) during emulsion preparation, simplifying the technological process.

In the technology of meat emulsion production, the dispersed state of the components and the degree of binding of moisture and fat are of significant importance. Indicators such as moisture content, water holding capacity (WHC), and fat holding capacity (FHC) are key to assessing the quality of cooked sausages. The results of determining these functional and technological indicators are presented in Table 4.

The addition of pumpkin seed protein isolate to the "Military" cooked sausage formulation positively influences the stability of the meat emulsion. Analysis of model samples with varying isolate concentrations revealed that the optimal amount is 4.5 g per 100 g of product. This dosage contributes to the improvement of both organoleptic and functional-technological characteristics of the sausage emulsion, as evidenced by the high water-holding and fat-holding capacity of the finished sausage.

"Military" cooked sausage can be utilized in the food industry both as a standalone product, pairing well with alcoholic and non-alcoholic beverages, and as an ingredient for preparing various dishes – salads, soups, fillings,

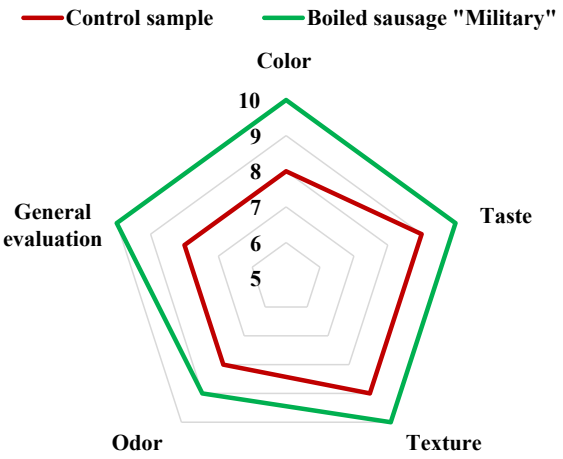

Figure 1 – Organoleptic evaluation profiles of cooked sausage "Military" with the addition of land snail meat enriched with pumpkin seed protein isolate

Source: compiled by the author

etc. In food industry enterprises and catering establishments, "Military" sausage is recommended to be stored in poly-styrene, protein-based, or natural casings.

Conclusions. The conducted research substantiates the development of an innovative "Military" cooked sausage with enhanced nutritional value, specifically designed to meet the demanding dietary needs of Ukrainian military personnel. The key findings are:

1. The study confirms the feasibility and strategic importance of utilizing alternative protein sources, specifically *Helix pomatia* meat and pumpkin seed protein isolate, in cooked sausage production. This approach addresses the limitations of conventional meat products in providing comprehensive nutrition for military personnel in field conditions.

2. Through mathematical modeling and experimental validation, the optimal formulation of the "Military" sausage was determined to be 18 g of *Helix pomatia* meat and 4.5 g of pumpkin seed protein isolate per 100 g of product. This ratio ensures superior organoleptic qualities and enhanced nutritional value.

3. Organoleptic analysis confirmed that the "Military" cooked sausage possesses a highly acceptable taste profile, comparable to that of traditional meat products, while being healthier due to the lower fat content and high protein content. This indicates its potential for wide acceptance among military personnel.

4. The incorporation of pumpkin seed protein isolate significantly improves the functional and technological characteristics of the sausage meat. Specifically, it enhances the water-

Table 4 – Functional and technological properties of the "Military" cooked sausage sample and the control sample (n=5, P≥0,95)

Sample	WHC, %	FHC, %	Water, %	Acidity
Control	73.4	71.0	68.5	6.2
"Military" cooked sausage	74.2	73.8	67.5	6.3

Source: compiled by the author

holding capacity (by 0.8% to 74.2%) and fat-holding capacity (by 2.8% to 73.8%) compared to traditional formulations, leading to improved stability and consistency of the product.

5. This research provides a scientifically grounded framework for the production technology of the "Military" cooked sausage, incorporating *Helix pomatia* meat and pumpkin seed protein isolate. This innovation contributes to a broader range of nutritionally enhanced meat products for Ukrainian military personnel, ultimately supporting their operational effectiveness and well-being.

Further research will focus on assessing the safety, shelf-life stability, and nutritional efficacy of the developed "Military" sausage in extended field trials. Moreover, the potential integration of other underutilized protein sources will be explored to further optimize the nutritional profile and sustainability of military food provisions.

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МОДЕЛЮВАННЯ ТЕХНОЛОГІЇ М'ЯСНИХ ВАРЕНИХ ФАРШЕВИХ ВИРОБІВ З ВИКОРИСТАННЯМ АЛЬТЕРНАТИВНИХ БІЛКІВ

В умовах сьогодення забезпечення українських військовослужбовців повноцінним харчуванням з високою біологічною цінністю є стратегічно важливим завданням. Традиційні м'ясні продукти не завжди відповідають вимогам до харчування в польових умовах та сучасним трендам здорових дієт, особливо зважаючи на зростаючу потребу в білку. Використання альтернативних джерел білка та оптимізація рецептур м'ясних виробів – перспективний напрямок для вирішення цієї проблеми. В даному дослідженні представлена розробка інноваційної рецептури вареної ковбаси «Військова», що включає равликів виду Helix pomatia та ізолят білка з гарбузового шроту. Це дозволяє підвищити харчову цінність продукту та раціонально використати відходи харчових виробництв. М'ясо равликів – джерело повноцінного білка, вітамінів та мікроелементів, з низьким вмістом жиру. Ізолят білка з гарбузового шроту – концентроване джерело рослинного білка, багатого на незамінні амінокислоти. Шляхом математичного моделювання визначено оптимальне співвідношення: 18 г м'яса равликів та 4,5 г ізоляту білка гарбузового шроту на 100 г ковбаси. Це забезпечує високі органолептичні та фізико-хімічні показники. Органолептична оцінка підтвердила відмінні смакові якості «Військової» ковбаси. Фізико-хімічні дослідження показали, що розроблена рецептура покращує функціонально-технологічні характеристики фаршу. Вологоутримуюча здатність (ВУЗ) «Військової» ковбаси становить 74,2%, на 0,8% вище контролю. Жироутримуюча здатність (ЖУЗ) також вища контролю на 2,8% та становить 73,8%. Ізолят білка гарбузового шроту покращує стабільність фаршевої системи та консистенцію. Результати проведеного дослідження дозволяють науково обґрунтувати технологію виробництва вареної ковбаси «Військова». Технологія передбачає додавання равликів виду Helix pomatia та збагачення ізолятом білка з шроту насіння гарбуза. Це дозволить розширити асортимент м'ясних виробів із підвищеною харчовою цінністю для військовослужбовців в Україні. Перспективи подальших досліджень включають вивчення показників безпечності, термінів зберігання та можливості використання інших видів альтернативних джерел білка. Дана розробка є інноваційним кроком у забезпеченні українських військових високоякісними продуктами, що сприятиме зміцненню їхньої боєздатності та здоров'я.

Ключові слова: *математичне моделювання, оптимізація рецептури, відходи харчових виробництв, альтернативні білки, варені ковбаси, військові раціони, здорова дієта.*

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