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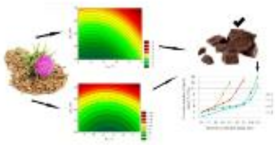
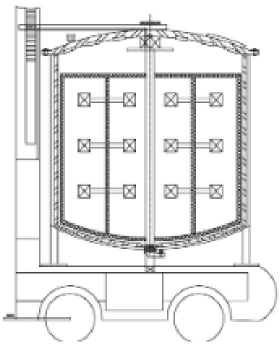
ENERGY-SAVING TECHNOLOGIES AND EQUIPMENT

ISSN (print) 1729-3774, ISSN (on-line) 1729-4061

Technology and Equipment of Food Production





UDC 637.523:355.65
DOI: 10.15587/1729-4061.2023.292777

DEVELOPMENT OF TECHNOLOGY OF COOKED SAUSAGES WITH A CHANGED FATTY ACID COMPOSITION FOR MILITARY PERSONNEL IN THE ARMED FORCES OF UKRAINE

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The peculiarities of the nutrition of servicemen of the Armed Forces of Ukraine, the requirements for the chemical composition of daily rations, and calorie content were analyzed. It was established that the diet of the military has an insufficient volume of proteins, carbohydrates, and vitamins, in particular, vitamins A and C. It is noted that the food of the analyzed category of people contains an excess of lipids, which are unbalanced in terms of fatty acid composition. Boiled sausage with a changed chemical composition is proposed to ensure the rational nutrition of military personnel.

The justified formulation and technology of boiled sausage are presented.

A feature of the development is the use of fat emulsion from internal pork fat and olive oil in a ratio of 1:1. To stabilize the emulsion, dry milk was added in the amount prescribed by the recipe. It was established that the addition of fat emulsion to the hydrated proteins of low-fat raw materials, beef and chicken, made it possible to stabilize the minced meat system, to obtain a tender, juicy and, at the same time, elastic consistency.

The combination of internal pork fat and olive oil in the recipe of cooked sausage made it possible to increase the mass share of poly- and monounsaturated fatty acids by 10.5 % and reduce the share of saturated fatty acids. However, the use of only two fats did not balance the proportion of ω-3 fatty acids. To enrich ω-3 fatty acids, it is recommended to add soybean or rapeseed oil.

The use of dietary chicken, fats rich in monounsaturated fatty acids, vitamin A and vitamin C allowed us to devise a recipe for cooked sausage of high quality and a changed chemical composition. Consumption of this product could balance the diet and increase the resistance of the personnel of the Armed Forces of Ukraine to negative external factors

Keywords: fatty acids, essential nutrients, fat emulsion, olive oil, internal pork fat

Received date 04.10.2023
Accepted date 06.12.2023
Published date 28.12.2023

***How to Cite**: Savinok, O., Novgorodska, N., Ovsienko, S. (2023). Development of technology of cooked sausages with a changed fatty acid composition for military personnel in the armed forces of ukraine. Eastern-European Journal of Enterprise Technologies, 6 (11 (126)), 24–32. doi: https://doi.org/10.15587/1729-4061.2023.292777*

1. Introduction

Each food ingredient performs one or another function in metabolic processes: energetic, plastic, bioregulatory, immunoregulatory, adaptive-regulatory, rehabilitation, and motivational-signaling functions. Performance of the listed functions can be provided by appropriate food products. Energetic and plastic function is provided by products included in the basic diet. Other listed functions are performed by components of fruits, vegetables, and spices [1].

Boiled sausages can be included in the main diet. In addition to pleasant taste characteristics, cooked sausages contain proteins, 10–12 %; fats, 30–35 %; moisture, 70–75 %. Due to this ratio of the main chemical components, cooked sausages have a high level of digestibility and are recommended for various categories of citizens. However, one of the main disadvantages of this group of products is the presence of only animal fats in the recipe. The fatty acid composition of fats of animal origin does not correspond to the balanced fatty acid formula for the human body. The product should contain mono- and polyunsaturated fatty acids. Therefore, improving the ingredient composition and production technology of boiled sausages is an urgent task for scientists. Especially if a new product is being developed for military personnel, whose nutrition requires special attention.

2. Literature review and problem statement

A person's daily diet should consist of various products in order to ensure his/her full functional activity.

Nutrition plays a particularly important role for military personnel. Constant stress, stress at the level of physical capabilities require the most balanced diet in terms of essential substances.

According to the expressed position of the International Society of Sports Nutrition [2], for specialists who are involved in the performance of special tasks and work under extreme conditions, energy needs are unknown and may differ depending on professional tasks. General recommendations should include providing and timing adequate calories, macronutrients, and fluids to meet daily needs, as well as strategic nutritional supplementation to improve physical, cognitive, and occupational performance. These guidelines should reduce the risk of injury, obesity, and cardiometabolic disease; reduce the probability of a fatal error; promote professional readiness. The authors noted that military personnel may also benefit from caffeine, creatine monohydrate, essential amino acids, protein, polyunsaturated fatty acids, beta-alanine, and L-tyrosine, especially under conditions of high stress.

In [3], the impact of extreme conditions and negative energy balance on the cognitive functions of US Army servicemen was investigated. The simulated conditions of combat and training operations allowed the authors to establish certain dependences. Energy deficits led to increased risk-taking with lower self-control and fatigue. The authors note that maintaining energy balance does not improve other aspects of cognitive function or mood, but prevents increased risk and improves self-control, reduces fatigue. Therefore, when organizing the nutrition of athletes and military personnel who perform tasks with significant physical load, it is necessary to pay attention to the energy value of the rations and exclude a calorie deficit. These results are valuable for the development of new products balanced in terms of energy and biological value.

Work [4] reports the study of energy supply issues for Norwegian military personnel under cold conditions. It is noted that physical exertion in cold weather leads to a serious energy deficit during military operations. Daily energy expenditure averaged 5480 kcal/day during training in the range of ambient temperatures: from –26 °C to –6 °C. These energy costs do not correspond to normal combat rations (3842 kcal/day) or arctic rations (5177 kcal/day) in terms of calories. Energy deficit under such conditions leads to a decrease in body weight, negative protein balance, suppression of androgenic hormones, increased systemic inflammation and deterioration of physical performance. A severe energy deficit during military training in cold weather reduces lower body strength. Decreased lower body strength due to energy deficits can jeopardize the success of a military mission. Lower body strength was determined using a vertical jump test performed before and after the training operation. The recommended measure is to increase the energy density of the diet (i.e. energy per unit mass of food). Consumption of high-fat and energy-dense foods mitigates the negative physiological effects of energy deficiency and supports physical performance during cold-weather military operations. Therefore, it is necessary to choose high-energy food products with a significant proportion of fat for military personnel who perform tasks under adverse climatic conditions.

Similar studies to determine energy requirements were carried out for the Canadian Armed Forces (CAF) and other military personnel. A review [5] of studies showed that energy requirements in temperate/hot climates (10 °C to >25 °C, depending on humidity) range from 3300 kcal/day to 6000 kcal/day. Energy requirements in cold environments (temperatures <10 °C, including arctic conditions) range from ~4000 kcal/day to >6000 kcal/day. Carrying out tasks in hard-to-reach places and wearing heavy clothes leads to a significant increase in energy consumption under cold conditions. However, the authors do not recommend generalizing the energy costs of CAF military units to those of other military contingents. Adequate nutrient requirements will vary due to differences in demographics, training requirements, standard operating procedures, type of activity, and composition of field rations.

In work [6] it is shown that the caloric content of the ration is determined for military personnel of the Republic of Bulgaria – 3700 kcal, which corresponds to macronutrients: 144.7 g of proteins, 468.8 g of carbohydrates, and 109.7 g of fats. According to the accepted NATO standard (STANAG 2937 NATO, 2013), the caloric content of the daily ration for NATO armies should be 3900 kcal. However, the research conducted by the authors made it possible to note that the food models implemented in the Bulgarian army correspond to the national and physiological norms of nutrition and provide the energy needs of military personnel participating in operations. Studies that show the correspondence between the physiological needs of the Bulgarian military and the performance of tasks under adverse weather conditions have not been found. The calorie content of 3700 kcal is calculated for a moderate climate. Therefore, it can be noted that the caloric content of the diet of Bulgarian military personnel, who may be assigned to perform tasks in the Northern regions of the planet, needs to be studied and analyzed.

Nutritional imbalance leads to the appearance of excess adipose tissue. Such a conclusion is stated in work [7] after researching the nutritional status of the officers of the border service of Poland. The authors identified the main cause of the violation. Border guards with excess adipose tissue ate irregularly and did not consume enough fruits and vegetables. This violation is not related to insufficient food products, but rather to ignorance of the basic principles of nutrition. To solve the problem, the authors suggested increasing the awareness of border guards on nutrition issues.

Great importance is attached to the problem of obesity among military personnel in the USA. The review of studies on the problem of obesity [8] made it possible to determine its basis. The main reasons that contribute to obesity are consumption of unhealthy high-energy food, lack of regular training. The recommended measures proposed by the scientists consisted in educational work with civil servants at various levels and at various contact points: in hospitals, in catering establishments, in the area where personnel are located, etc.

The nutrition of the personnel of the Armed Forces of Ukraine (AFU) is determined by a food set in accordance with the established nutritional norms for people engaged in particularly heavy work. The medical and biological requirements for military nutrition are based on the principles of balanced rations in terms of energy expenditure, content and ratio of the main nutrients of proteins, fats, carbohydrates, vitamins and minerals. These requirements are defined in accordance with physiological recommendations, three meals a day, sufficient food during training and combat activities [9]. According to the norms of physiological needs for military servicemen in basic nutrients and energy, the daily energy consumption of military personnel is from 3000 to 4500 kcal [10]. The average value (3750 kcal), as a rule, is taken as the basis for normalizing the energy needs of the main military specialists with an average body weight of 70 kg. This value is taken as the basis for calculating the caloric content of the combined military ration of 3,500–4,100 kcal (this value of the energy requirement corresponds to the

IV group of physical labor intensity) [11]. The total calorie content of the daily field set of products should also be at least 3500 kcal [12].

The general military ration should contain (g): proteins – 148, fats – 142, carbohydrates – 595 [13]. That is why the diet should primarily include products with a different chemical composition. First of all, protein products with an increased amount of sulfur-containing amino acids (fermented and rennet cheeses, beef, chicken). Secondly, products with a high content of polyunsaturated fatty acids and phosphatides (liver, heart). Thirdly, products with a high content of vitamins C, P, K, E, A (fruits, juices, liver, fish) and salts of calcium, potassium, magnesium, iron, copper (milk and fermented milk products, grain products, fruits and vegetables). Taking into account significant loads, a constant state of stress, the diet should include components that perform a rehabilitation function, i.e. products that have a reduced proportion of sodium, a balanced fatty acid composition of lipids, and the presence of high molecular weight carbohydrates.

The personnel of the armed forces of Ukraine are fed in accordance with the list of established food products. This list is determined by the Resolution of the Cabinet of Ministers of Ukraine dated 03/29/2002 No. 426 "On food standards for servicemen of the Armed Forces of Ukraine and other military formations" and the order of the Ministry of Defense of Ukraine dated 26/02/2007 No. 66 "On the organization of food for the personnel of the Armed Forces of Ukraine by involving business entities" [14]. The daily menu is formed in accordance with the wishes of servicemen and the standards of provision. However, the level of self-education in the direct selection of dishes, which are presented in a wide range in the dining room, does not determine a balanced set of essential components of food, and, accordingly, the employee does not receive the daily rate of these substances. In addition, a significant proportion of food products and ready-made meals are refined in terms of biologically active substances, which negatively affects the health of military personnel. The energy value of the servicemen's diet should be distributed as follows: breakfast – 30–35 %, lunch – 40–45 %, dinner – 20–30 % [15].

An important nutritional criterion is biological value, which characterizes the quality of proteins and is due to the presence of essential amino acids in them.

The analysis of food rations of military personnel [16] made it possible to establish the imbalance of the protein quota of the normative and actual rations due to an overload of vegetable proteins and a deficiency of complete animal proteins. Scientists have established that the ration defined by the order [14] contains 41 g of animal and 81 g of vegetable proteins [16], and the actual one contains an average of 33.3 g and 76.0 g, respectively. The low content of animal proteins leads to an unbalanced amino acid score [17]. The actual consumption of protein does not at all satisfy the physiological needs of a person of the IV group of labor difficulty, which includes the activities of military personnel [18].

Studies have shown that the fat quota of both normative and actual diets exceeded the recommended physiological needs for lipids (100 g) by 3.9 and 8.3 %, respectively. It was established that these diets are not balanced in terms of fatty acid content [12].

The indicator of the carbohydrate share of the actual ration turned out to be 585.0±3.5 g, which is 8.0 % less than the carbohydrate quota of the standard ration of military personnel (635.30 g). In addition, the actual provision of carbohydrates does not meet the norms of physiological needs for the able-bodied population of the IV group of physical activity (624.0 g per day) [17].

Evaluating the vitamin availability of the actual and normative rations, the authors of [19] found discrepancies. The content of vitamin A in the actual (0.84±0.03 mg) and normative (0.9 mg) rations is inferior to the daily norms of physiological needs (1 mg) by 16 and 10 %, respectively. The content of vitamin B2 in the actual diet was 1.34±0.01 mg, which is 13.5 % less than the standard (1.55 mg). At the same time, neither actual nor normative rations correspond to the physiological daily needs of young people (2.0 mg). The average annual quota of vitamin C in the daily actual ration was 43.52±1.63 mg, which meets only 52.3 % of the daily physiological needs of the body of military personnel (at least 80.0 mg per day). In addition, this indicator is 15 % less than the standard ration (51.23 mg).

Annually, from March 15 to June 15, additional vitaminization is carried out by issuing 1 "Hexavit" dragee/day, which makes it possible to ensure the physiological needs of military personnel in vitamins. However, in other months of the year, the deficiency of vitamins A, B2, and C persists [14].

Despite the quality of raw materials and food products that are delivered to the military units, a large role in the construction of daily food rations is played by the preparation of the menu. Better assimilation of food is facilitated by taking into account individual habits, national and household traditions in nutrition [20], the use of combined meat and vegetable products [21], which have high biological value and physiological and functional properties. To preserve the biologically valuable components of food, the method of processing raw materials is important [22].

Summarizing the general analysis of modern problems in the nutrition of the personnel of the Armed Forces of Ukraine, the main solution of which can be the introduction into the diet of products enriched with essential nutrients.

As a basis, for improvement, choose such products that are basic in the diet. They can include meat products of various types.

It is possible to reduce the proportion of saturated fatty acids in meat products and to enrich them with unsaturated ones by using various vegetable oils in natural, blended or emulsified form. Natural oils have not become widespread in meat products due to the negative impact on the texture of the finished product. Meat products with a broken tissue structure of the main raw material are convenient for modifying recipes.

Blended oils were used for meat pastes [23]. The authors recommend mixtures of various vegetable oils with a proportion of 10 % pork fat replacement. The obtained products were characterized by high organoleptic indicators. Replacing the main meat raw material with a protein-fat emulsion with vegetable oils contributed to increasing the nutritional value of products, optimizing the chemical composition of the diet of potential consumers due to the content of antioxidant vitamins, PUFAs, proteins, and trace elements.

To create restructured ham products of increased nutritional and biological value, scientists [24] recommend adding a protein-fat emulsion to the recipe. The emulsion consists of milk proteins, blood, a mixture of pork and turkey fat, and turkey skin. The share of addition to the main raw material, 20 %, made it possible to ensure the ratio of the sum of unsaturated and saturated fatty acids in the product of 66.42:28.99 against the recommended 70:30 and to improve the biological value of the ham product in terms of the content of essential amino acids.

An overview of the main developments in the use of emulsions and gels from various types of fats of vegetable and animal origin is given in article [25]. The authors found that there is active development of new meat products such as sausages, patties, hamburgers, etc., by replacing their natural fat with healthier oleo gels, rich in polyunsaturated fatty acids (PUFA) and monounsaturated fatty acids. To replace animal fat in meat products, oleo gels are made from vegetable oils high in MUFA (such as canola oil and olive oil) and PUFA (such as grapeseed oil, soybean oil, flaxseed, sunflower, pumpkin, chia, etc.).

An example of the use of oleo gels is bologna type sausage with a modified recipe [26]. To replace animal fat, oleo gel from rice bran and soybean oil was added to the minced meat. The introduction of oleo gel did not have a negative effect on sensory parameters: aroma, taste, texture, juiciness. The difference was only in color. In the samples with animal fat, the color on the product section was more intense. Test samples according to the classic formulation had larger lipid globules than samples with oleo gel. According to the authors' conclusion, the developed recipe of sausage with the replacement of animal fat with oleo gel had a more favorable profile of fatty acids.

In Frankfurt sausages, it was proposed to replace beef fat with an organogel from rapeseed oil [27]. Ethyl cellulose and sorbitan monostearate were used to structure the oil. The authors established that the use of oleo gel from rapeseed oil ensured the necessary density of the product. Replacement of beef fat with regular or structured rapeseed oil, organogel, made it possible to produce traditional meat products with a lower proportion of saturated fatty acids.

In work [28] it is proposed to replace animal fats with emulsion gels from olive oil and chia oil in sausages. Cold gelling agents – transglutaminase, alginate, or gelatin – were used to stabilize emulsion gels. In the experimental products, the fatty acid composition was improved, the proportion of saturated fatty acids was reduced. The gelling agents provided sufficient moisture and fat binding capacity, acceptable texture and resistance to oxidation during storage.

Emulsions stabilized by mannoprotein MP112 were used to reduce the fat content of sausages [29]. Mannoprotein MP112 was obtained from yeast by enzymatic hydrolysis of the myxobacteria β-1,6-glucanase GluM. The fat fraction of the emulsion contained 20 % olive oil and 80 % sunflower oil. The authors noted that replacing animal fat with MP112 emulsion in sausages significantly reduced fat content and increased moisture and protein content without adversely affecting sensory parameters. Replacement of animal fat with MP112 emulsion significantly improved the nutritional composition of emulsified sausages, they had a higher PUFA/NFA ratio and a lower n-6/n-3 ratio.

Gel-like emulsion systems containing peanut and linseed oil were used to partially or completely replace beef fat in emulsified sausages [30]. The developed emulsion allowed the authors to reduce the total share of fat in the product to 40 %, the energy value to 27 %. The level of saturated fatty acids and cholesterol in the product has decreased, the share of mono- and polyunsaturated fatty acids has increased. The obtained emulsion contributed to the improvement of the stability of the emulsion of minced sausage before and during cooking. The authors' overall results showed that emulsions based on peanut and linseed oils can be successfully used for emulsified sausage products to provide a healthier lipid profile with good technological and sensory quality.

The review of studies made it possible to find out several problems that need to be solved. The nutrition of military personnel of Ukraine requires correction of the chemical composition of the diet, without reducing the total daily caloric intake. At the same time, the excess of animal fats in the diet poses threats to the health of the military, especially now, in the period of war and constant stress. Research conducted in various countries of the world was focused on the creation of low-calorie meat products with the addition of vegetable oils rich in unsaturated fatty acids. The problem with the development of high-calorie basic food products, which would be aimed at consumers with difficult working conditions, has not been solved. Accordingly, conducting experimental and practical research into the issue of developing the technology of sausage products with a changed fatty acid composition for the military of the Armed Forces of Ukraine is relevant.

3. The aim and objectives of the study

The purpose of our research is to devise the technology of cooked sausage with a changed fatty acid composition for the military of the Armed Forces of Ukraine. The developed sausage products will satisfy the needs of the military in polyunsaturated fatty acids, balance the ingredient composition of the diet, reduce the negative impact of a prolonged state of stress, and, at the same time, ensure the normalized daily caloric intake.

To achieve the goal, the following tasks were set:

– to investigate the peculiarities of the minced meat preparation technology and to devise a recipe for cooked sausage with a changed fatty acid composition;

– to study the fatty acid composition of cooked sausages according to standard and developed recipes;

– to investigate the effect of vitamins A and C on the functional properties of cooked sausage.

4. The study materials and methods

The object of our research is the recipe and technology of cooked sausage with a changed chemical composition. The main research hypothesis assumes that the addition of olive oil and internal pork fat to the minced meat base should balance the fatty acid composition of the product.

Animal products, in particular meat, are a source of complete proteins. Fats in meat products are represented by saturated and unsaturated fatty acids, in which only pork fat has a predominant proportion of monounsaturated fatty acids. According to the proposed ideal formula of the fatty acid composition of dietary fat for humans [31], the ratio should be as follows:

– ώ-6 polyunsaturated fatty acids (PUFA) – 6.4 %;

– ώ-3 polyunsaturated fatty acids (FA) – 1.6 %;

– saturated fatty acids (FA) – 23 %;

– monounsaturated (MAH) – 69 %.

Beef fat contains 55 % NFA, 43 % MFA, pork – 40 % NFA, 45 % MFA [31]. Accordingly, the use of only animal fat in the diet will not make it possible to balance the fatty acid composition. Therefore, the most rational solution to the problem can be a complex combination of animal fat in products with vegetable, in particular, olive oil, which consists of 75 % of MFA.

The main raw materials for sausage production were beef, poultry, pork fat, olive oil, chicken eggs and milk powder. Spices and sodium nitrite were added to the minced meat in accordance with the classic recipe for cooked sausage – "Milk" sausage DSTU 4436:2005. The sausage production technology complied with regulatory documents (DSTU). Determination of the fatty acid composition of the product was carried out by a calculation method based on literature data [31, 32]. Sensory indicators were determined by conducting a tasting by a group of specially trained tasters in a specialized laboratory. Guided by standards: ISO 8589:2007 "Sensory analysis – General recommendations for the design of test rooms", ISO 13299:2003 "Sensory analysis – Methodology – General guidelines for establishing a sensory profile", ISO 4121:2003 "Sensory analysis – Guidelines for the use of quantitative scales of answers", ISO 3972-1991 "Sensory method of analysis – Method of research of taste sensitivity". Determination of the hydrogen index in raw materials and products was carried out according to the standard procedure "Meat and meat products. Determination of pH (control method)" (DSTU ISO 2917:2001). Determination of the content of sodium nitrite in sausage products was carried out according to the standard procedure "Meat and meat products. Method for determining the total amount of nitrites (control method)" (DSTU ISO 2918:2005).

5. Research on the technology of cooked sausages with a changed fatty acid composition

5. 1. Study of the peculiarities of the minced meat preparation technology and development of the recipe for cooked sausage with a changed fatty acid composition

At the first stage of the research, the recipe of the sausage was worked out according to sensory indicators. The introduction of the fat fraction was carried out at the final stage of preparation of minced meat in the form of a fat emulsion in concentrations of 9, 12, 15, 20, 25 % to the mass of the main raw material (Table 1). The grinding process was finished when the mincemeat temperature reached 12–13 °C and a homogeneous consistency was reached. Preparation of fat emulsion was carried out according to the recipe: pork fat, olive oil and dry milk in a ratio of 45:45:10. Fat emulsion preparation technology: grinding raw pork fat into a homogeneous paste, adding olive oil, adding dry milk and spices. The total duration of grinding and emulsifying the fat emulsion is 6–7 minutes to a uniform consistency.

During the preparation of minced meat, at the stage of fine grinding of beef, 15 % of flake ice was added and 10 % after poultry meat. In the production technology of minced sausages according to the classic recipe, ice was added after beef and semi-fat pork. In our research, the yield of the finished product is lower than the standard, in all experimental samples it is: for the sample with the addition of 9 % fat emulsion, the yield of the product is 104.2±0.2 %, 12 % – 105.7±0.2 %, 15 % – 106.3±0.1 %, 20 % – 106.8±0.3 %, and at 25 % – 107.8±0.1 %. In the control sample, made according to the recipe of "Milk" sausage (Table 2), the normative yield is 109 %, the practical yield obtained in the laboratory is 108±0.7 %. The hydrogen pH index of the finished minced meat for all samples was 6.65±0.05. The mass fraction of moisture in the experimental samples was: 64.8±0.03 % from 9 % fat mixture, 65.1±0.03 % from 12 %, 65.5±0.02 % from 15 %, 65.9±0.02 % from 20 %, 25 % – 66.3±0.02 %, in control – 67.1±0.03 %. An increase in the mass fraction of fat in the product reduces the fraction of moisture in the finished product. However, the use of a fat emulsion in this technology, adding it to a well-hydrated fraction of proteins, makes it possible to evenly distribute the ingredients in the volume of minced meat and provide a stable emulsion that firmly retains moisture during heat treatment and ensures an increase in yield.

According to the results of the tasting evaluation, sensory indicators with high scores were found in samples with fractions of fat emulsion – 15 and 20 %. According to sensory indicators, when adding 9 % fat mixture, the product had a specific smell, a taste of dry milk, and a loose consistency. The sample with a fat mixture concentration of 12 % had a more pleasant taste, smell and consistency did not differ. The sample with a concentration of 15 % fat emulsion had a more elastic structure, a pleasant taste, but not juicy enough. The sample with a concentration of 20 % had a pleasant rich taste and aroma, characteristic of cooked sausage, the consistency is elastic, juicy, the aftertaste of dry milk is almost not felt. In the sample with 25 %, the loosening of the consistency was noted, although the taste and aroma had the maximum rating. Therefore, in further studies, the basic recipe included 23 % of the emulsion by weight of the main raw material, and the proportion of fats was 20 % (Table 2).

Table 1

Prototype formulations

Raw materials	Sample 1 (9 % fat emulsion), %	Sample 2 (12 % fat emulsion), %	Sample 3 (15% fat emulsion), %	Sample 4 (20 % fat emulsion), %	Sample 5 (25 % fat emulsion), %
Basic raw materials, %					
Stocked Beef „Extra Class"	35	35	35	35	35
Chicken fillet	54	51	48	43	38
Chicken eggs or mélange	2.0	2.0	2.0	2.0	2.0
Pork fat	4.05	5.4	6.75	9.0	11.25
Olive oil	4.05	5.4	6.75	9.0	11.25
Dry milk	0.9	1.2	1.5	2.0	2.5
In total	100	100	100	100	100
Auxiliary raw materials, g per 100 kg of basic raw materials					
Kitchen salt	2090				
Sodium nitrite	7,1				
Granulated sugar or glucose	120				
Black pepper	120				

Table 2

The basic recipe of the developed boiled sausage

Basic raw materials, %	
Stocked Beef „Extra Class"	35
Chicken fillet	40
Chicken eggs or melange	2
Raw pork fat	10
Olive oil	10
Dry milk	3
In total	100
Auxiliary raw materials, g per 100 kg of basic raw materials	
Kitchen salt	2090
Sodium nitrite	7.1
Granulated sugar or glucose	120
Black pepper	120

The sausage produced according to the modified recipe had a pleasant taste, a tender and elastic consistency. The presence of olive oil in the recipe was not felt. Therefore, in the future, was taken as a basis.

5. 2. Study of the fatty acid composition of cooked sausages according to standard and developed recipes

Taking into account all the recipe components (Table 3), calculations were made of the fatty acid composition of "Milk" sausage and cooked sausage according to the new recipe (Table 4).

The fatty acid composition of boiled sausage according to the developed technology is given in Table 4.

Generalized calculations of the formula of fatty acid composition are given in Table 5. According to our results, the fatty acid composition of the product remains unbalanced in terms of ω-3 fatty acids. In general, due to the use of olive oil, the mass proportion of monounsaturated fatty acids increases.

Table 3

Fatty acid composition of raw materials and boiled sausage "Milk"

Product	Fatty acid content							
	UFA		Poly- and monounsaturated FA		ω-6		ω-3	
	raw material, %	boiled sausage, g per 100 g	raw material %	boiled sausage, g per 100 g	raw material, %	boiled sausage, g per 100 g	raw material, %	boiled sausage, g per 100 g
Stocked Beef „Extra Class" [31]	6.5	2.275	5	1.750	0.4	0.140	0.12	0.042
Semi-fat pork [31]	12	7.200	15	9.000	2.8	1.680	0.7	0.420
Chicken eggs or melange [31]	3.0	0.060	5	0.100	1.2	0.024	0.06	0.001
Powdered milk [31]	11.26	0.338	6.76	0.203	1.13	0.034	0.05	0.002
Average for sausage	–	9.873	–	11.053	–	1.878	–	0.465

Table 4

Fatty acid composition of boiled sausage according to the developed recipe

Product	Fatty acid content							
	UFA		Poly- and monounsaturated FA		ω-6		ω-3	
	raw material, %	boiled sausage, g per 100 g	raw material %	boiled sausage, g per 100 g	raw material, %	boiled sausage, g per 100 g	raw material, %	boiled sausage, g per 100 g
Stocked Beef „Extra Class" [31]	6.5	2.275	5	1.750	0.4	0.140	0.12	0.042
Chicken fillet [31]	2	0.800	4	1.600	1.6	0.640	0.07	0.028
Chicken eggs or melange [31]	3.0	0.060	5	0.100	1.2	0.024	0.06	0.001
Crude pork fat [32]	45	4.500	50	5.000	8.4	0.840	2.2	0.220
Olive oil [31]	12	1.200	75	7.500	12	1.200	0	0.000
Milk powder [31]	11.26	0.338	6,76	0.203	1.13	0.034	0.05	0.002
Average value for sausage	–	9.173	–	16.153	–	2.878	–	0.293

Table 5

Calculation of the formula for the fatty acid composition of boiled sausages

Fatty acids	Ideal formula of fatty acid composition of human fat, %		Formula of fatty acid composition of edible fat of experimental sausage, %	The formula of the fatty acid composition of the edible fat of the sausage "Milk", %.
	Study [31]	Study [9]		
Saturated FA (SFAs)	23.0	30.0	32.2	42.5
Monounsaturated (MUFAs)	69.0	60.0	56.9	47.5
ώ-6 polyunsaturated fatty acids (PUFAs)	6.4	10.0	10.1	8.1
ώ-3 polyunsaturated fatty acids (PUFAs)	1.6		1.1	2.0

According to our results, the fatty acid composition of the product remains unbalanced in terms of ω-3 and ώ-6 fatty acids, according to study [31]. In general, due to the use of olive oil and internal pork fat, the mass proportion of poly- and monounsaturated fatty acids increases to 68.1 %.

If we compare according to the ideal formula from study [9], the imbalance in fatty acid composition is from 1.2 % to 3.1 %. This imbalance can be mistaken for an error. The chemical composition of meat raw materials is different for different batches, the fatty acid composition of cooked sausages will also be different, within the margin of error.

It should be noted that the use of poultry breast fillet and internal pork fat did not lead to a significant change in the proportion of proteins. However, poultry meat is characterized by a small proportion of connective tissue and has a predominant proportion of complete proteins, so changing the product formulation will contribute to the appearance of a dietary orientation in the product.

5. 3. Study of the effect of vitamins A and C on the functional properties of cooked sausages

To increase the biological value of the product, vitamins A and C were added to the basic formulation in a mass fraction of 0.25 %. The addition of vitamins slightly changed the organoleptic parameters in relation to the control. The presence of vitamin C contributed to the appearance of a more pronounced salty taste in the product and a rich pink color of minced meat on a slice. In general, the introduction of vitamins did not affect the organoleptic indicators of the studied products, which will allow recommending them for use in sausage products.

In addition to organoleptic studies, the hydrogen pH indicator and mass fraction of sodium nitrite were determined in the obtained samples. The results are given in Table 6.

Table 6

Study of the effect of vitamins on the functional parameters of sausages

Experimental specimens	Mass share $NaNO_2$, %	pH
With vitamin A	0.0041±0.05	6.6±0.05
With vitamin C	0.0034±0.03	6.5±0.05
CONTROL	0.0040.04±7	6.6±0.04

According to the conclusions made by other scientists, for example in [26], vitamins reduced the mass fraction of residual sodium nitrite in the experimental samples and did not affect the pH. Vitamin C is almost completely destroyed by heating, so its function will be limited by the intensification of the color formation process. Vitamin A is resistant to high temperatures, especially since sausages are cooked at temperatures of 80–85 °C, so its preservation in the finished product can be expected.

6. Discussion of the effectiveness of research into the technology of cooked sausage with a changed fatty acid composition

The development of the technology of cooked sausages with a changed fatty acid composition involves the use of olive oil and internal pork fat. The mixture of fats is added to the minced meat in the form of an emulsion, which ensures uniform distribution and stability of the product during heat treatment. The use of vegetable liquid oils in the form of an emulsion excludes their release after cooking and does not disturb the texture of the product, as evidenced by the described sensory indicators. The effective use of a mixture of animal fat and vegetable oil does not contradict the experimental studies of other scientists [25].

It should be noted that increasing the proportion of olive oil in the emulsion to more than 50 % of the total mass of fats, at the first stage of research, contributed to the loosening of the structure, therefore, for further research, the following ratio was used: pork fat, olive oil and dry milk in a ratio of 45:45:10. For the technology of cooked sausages, it is not advisable to exceed the share of liquid oil by more than 50 % during the preparation of the emulsion without using additional emulsifiers.

The analysis of test samples and controls made it possible to establish the relationship between the mass fraction of the emulsion in the product and the values of physicochemical indicators. In the control, a smaller proportion of fat due to the difference in the recipe composition and, accordingly, a larger mass proportion of moisture. For experimental samples, the introduction of fats in the state of a fat emulsion at the stage of maximum protein hydration contributed to the formation of a stable minced meat system that retains moisture well during high-temperature processing. The confirmation of this conclusion is the growth of the mass fraction of moisture in the finished product, yield and improvement of sensory indicators of experimental samples with a fraction of emulsion to the mass of the main raw material from 9 % to 25 %. The share of emulsion of 23 % by weight of the main raw material provided the best sensory indicators, therefore it is recommended for implementation.

The selected types of basic raw materials ensured an increase in the mass fraction of fatty acids in the finished product. In "Molochna" sausage according to DSTU, the mass fraction of fatty acids is 23.27 % (Table 3), in sausage according to the developed recipe – 28.5 % (Table 4), which is 5.23 % more. Therefore, an increase in the proportion of fats in products will ensure an increase in the energy density of the product. The introduction of such products into the diet will improve the cognitive functions of military personnel, increase their stability during the performance of tasks in adverse climatic conditions.

In addition to increasing the total share of fatty acids, the fatty acid composition of the product significantly changes according to the developed recipe. The proportion of poly- and monounsaturated fatty acids increases from 57.6 % for "Milk" sausage to 68.1 % for sausage according to the developed recipe, which increases the biological value of the product (Table 5).

However, the combination of internal pork fat and olive oil did not allow 100 percent balancing of the fatty acid composition (Table 5), the total share of polyunsaturated fatty acids increased, but ω-3 fatty acids decreased. This is a drawback of this development and needs to be eliminated in the future.

A separate emulsion production process allows vitamins to be added. Vitamin C acts as a sodium nitrite reducer and reduces its residual share in the product from 0.0047±0.04 % to 0.0034±0.03 % (Table 6). The positive effect of vitamins, in particular nicotinamide, on the recovery of sodium nitrite in sausage products and the reduction of its share in the finished product was noted in previous studies [33]. Vitamin A increases the biological value of the product and acts as an antioxidant.

Further research will be aimed at optimizing the fatty acid composition of cooked sausage in combination with fat-soluble vitamins.

7. Conclusions

1. To produce cooked sausage, fat raw materials are selected: internal pork fat, olive oil. Addition to minced meat is provided in the state of fat emulsion. Emulsion formula: pork fat, olive oil, dry milk in a ratio of 45:45:10. The peculiarity of the fat emulsion preparation technology: grinding raw pork fat into a homogeneous paste, adding olive oil, adding dry milk and spices. The total duration of grinding and emulsifying the fat emulsion is 6–7 minutes to a uniform consistency. It is planned to introduce a fat emulsion to the finely chopped mass of minced meat at the last stage of cutting. The rational share of the emulsion is determined based on the results of sensory studies. Samples with 20 and 25 % emulsion had high scores. For the basic formulation, the chosen share is 23 %.

A recipe for cooked sausage has been developed with portions of the main raw materials: top grade sirloin beef – 35 %; chicken fillet – 40 %; chicken eggs or mélange – 2 %; crude pork fat – 10 %; olive oil – 10 %; dry milk – 3 %. The mass of auxiliary materials is similar to the recipe of "Milk" sausage.

2. The fatty acid composition of the cooked "Milk" sausage was calculated according to the developed recipe. A comparative analysis of the ideal formula and fatty acid composition of sausages is presented. For the developed product, an increase in the share of monounsaturated fatty acids to 56.9 %, a decrease in the share of saturated fatty acids to 32.2 %, and an imbalance in ω-3 fatty acids were found. It is recommended in further studies to add soybean oil rich in ω-3 fatty acids to the composition of the emulsion.

3. The use of vitamins A and C helped increase the biological value and reduce the residual share of sodium nitrite in the finished product to 0.0034±0.03 %. Vitamins A and C can be added separately or in combination during the preparation of minced meat, but it is not mandatory. Their use is recommended for the prevention of diseases caused by physical exertion and a constant state of stress.

Conflicts of interest

The authors declare that they have no conflicts of interest in relation to the current study, including financial, personal, authorship, or any other, that could affect the study and the results reported in this paper.

Funding

The study was conducted without financial support.

Data availability

All data are available in the main text of the manuscript.

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating the presented work.

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