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FORMATION OF MEATBALL MASS AS A MULTICOMPONENT FOOD SYSTEM

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Abstract. The article discusses a scientifically based approach to the formation of cutlet mass as a multicomponent food system with increased nutritional density. The relevance of the work is determined by the need to create products that combine proteins of animal and plant origin and contain sufficient amounts of vitamins, minerals, and dietary fiber. The chemical composition of traditional cutlet mixture components and alternative plant raw materials is analyzed. Particular attention is paid to brewers' grains as a secondary product of grain processing, which contains significant amounts of protein, fiber, and minerals. Comparative studies have shown that brewers' grains significantly exceed wheat bread in protein and fiber content, making them a valuable functional ingredient. Based on theoretical and analytical data processing, a recipe for cutlet mass was developed using chicken fillet, brewers' grains, eggs, and whey. The nutritional value of the samples obtained was calculated and the nutritional density indices of the main nutrients, including proteins, fats, carbohydrates, dietary fiber, and B vitamins, were determined. It was found that the addition of brewer's grains increases the proportion of vegetable protein, enriches the product with fiber, and improves the absorption of amino acids due to the presence of B vitamins in egg and milk ingredients. The technological features of obtaining cutlet mass, including the preparation of raw materials, mixing of components, the effect of plant fiber on the consistency and ability of the system to retain moisture and fat, have been studied. The scientific novelty lies in establishing the functional role of brewer's grains as a texturizer and water-binding component in the structure of meat products when pre-hydration modified. The practical significance of the study lies in the possibility of using brewers' grains as an affordable protein-fiber ingredient in the production of meat products with improved technological and consumer characteristics while reducing production costs. The main conclusions of the study indicate the feasibility of using powdered brewers' grains hydrated in whey as an effective component of the recipe to improve the quality of minced meat products.

Keywords: multicomponent systems, cutlet mass, brewers' grains, whey, food density index.

Introduction. Formulation of the problem

Most foods produced today are complex, multi-component, heterogeneous mixtures, the condition of which depends on many factors. When creating complex food systems for the organization of rational nutrition, it is necessary to take into account a number of requirements regarding the availability of essential macro- and micronutrients, their balance, and compliance with the desired level of consumer preferences, based on the properties of the initial components. The most important task in modern technologies is to ensure the high nutritional density of multi-component products by selecting ingredients that contain a greater amount of nutrients per calorie. This is due to the fact that changes in the intensity of physical activity of modern humans have led to a significant reduction in energy expenditure, while the need for nutrients has remained quite high.

In recent years, healthy eating trends have continued to evolve, with consumers becoming increasingly interested in the nutritional value of products and their effects on human health. In 2024-2025, the main areas of health improvement included innovations in plant-based nutrition, technological advances in food production, and a growing interest in personalized diets [2].

For a long time, one of the leading trends has been ensuring a balanced protein intake. Animal proteins mainly provide a high-quality balance of amino acids, while plant proteins are more important for ensuring the necessary intake of nitrogen. The combination of animal and plant proteins in a multicomponent system allows the creation of biologically active amino acid complexes that ensure physiological completeness and a high degree of amino acid utilization for tissue synthesis processes. Complete protein assimilation is accompanied by the presence of minor substances in the product and their compliance with daily intake standards. This approach to ensuring a complete diet can be implemented in the formation of multicomponent food systems.

Analysis of recent research and publications

To meet the physiological and biological needs of the human body, priority is given to proteins of animal origin. The limited availability of protein resources requires their rational use, taking into account modern ideas about healthy eating as the basis for the creation of innovative production technologies and new or improved types of products.

Dietary recommendations provide for a daily protein intake of 0.8 g per kilogram of body weight [1]. However, protein must be obtained from various food sources. The food pyramid recommends eating red meat, poultry, fish, eggs, legumes, and nuts as foods that contain a significant amount of protein. Plant proteins are more environmentally friendly and play an important role in maintaining nitrogen balance in the body. The consumption of plant proteins has also been a trend in recent years, with increased consumption of plant-based foods by all population groups, not necessarily excluding animal products, but emphasizing a plant-based diet [2].

The combination of animal and plant components in the recipe has a number of advantages. Plant-based ingredients enrich the composition with fiber, vitamins, minerals, and antioxidants, which help reduce the risk of developing chronic alimentary diseases. At the same time, the production of plant-based ingredients is more environmentally friendly and requires fewer natural resources.

Another area of development for restaurants is the consumption of foods enriched with functional ingredients that have a positive effect on human health. For meat systems, such ingredients can include highly hydrophilic whey proteins, collagen, plant fiber with high fat-binding capacity, etc. When forming multicomponent mixtures to increase the content of minor and biologically active substances in the product, it is necessary to study the raw material sources of nutrients, isolate biologically active compounds in the form of an extract, paste, powder, or powder, and introduce them into the mixture in this form.

The use of secondary raw materials or waste from local food production is undoubtedly a positive direction in enriching multicomponent systems with functional ingredients. These include whey, brewer's grains, and other production waste products that are currently underutilized in the latest food production technologies. Innovations are aimed at increasing efficiency, reducing costs, and minimizing environmental impact. Thanks to the latest technologies, it is possible not only to improve the quality of food, but also to make it more sustainable and accessible to the general population.

Today, cutlets are made from various types of meat raw materials [20]. Cutlet production has always been a widely used technological direction, as this food product is easy to prepare, tasty, and nutritious. There are many different recipes and technological solutions for making cutlets. In a number of restaurants, this dish is produced according to approved documentation or technological cards developed at the enterprise [20]. The recipe composition of the product and the ratio of ingredients, the type of meat raw materials and the method of grinding, the type of heat treatment, and the method of serving the dish may vary.

Considerable attention is paid to ensuring the high taste properties of the product, achieving a loose, tender consistency, and in some products, a crispy crust on the surface, etc. The addition of soaked stale wheat bread to the recipe helps to bind the moisture that is released during protein denaturation [9]. The presence of fiber in the product contributes to significant liquid adsorption, its retention, and the creation of the desired shape and elasticity of the product.

High-quality cutlet mass is formed when meat from well-fed animals with a fat content of up to 10% is used for its preparation. If the meat is lean, fatty raw materials are added to the recipe (5-10% of the meat mass). The meat is trimmed of tendons, cut into pieces (50-100 g) and passed through a meat grinder [20]. Add stale wheat bread without crusts, previously soaked in cold water or milk, salt, and ground pepper to the minced meat, mix, pass through a meat grinder, add water or milk, mix, and beat [20]. The beating process is carried out to form a homogeneous mass, but in such a way that no fat is released from the resulting mass.

When producing cutlet mass from veal, which is rich in protein and characterized by a low fat content, a food product is obtained that is recommended in most types of special nutrition. Such cutlet mass contains enough fat to provide energy, essential fatty acids, and promote the absorption of fat-soluble vitamins (A, E, D, K). The high protein content makes this type of meat attractive for those who particularly need building material for muscles and to boost their immunity [9].

There are various approaches to making chicken fillet cutlets [3]. Cutlets are usually made from minced meat, as it is easy to mold and shape. Chopped cutlets are also tasty compared to minced meat cutlets [3]. The meat is not minced in a meat grinder or blender, so even after frying, every piece is noticeable. The cutlets do not fall apart in the pan, have the correct shape, and look appetizing.

Thus, forming the cutlet mixture as a multicomponent system allows you to create protein-containing products of increased nutritional value that contain functional ingredients and ensure high organoleptic properties of the finished product.

Purpose and objectives of the study. The aim of the work was to form a cutlet mixture based on animal and plant proteins using chicken fillet and brewers' grains, restored in whey.

Key objectives of the research:

1. Conduct a comparative analysis of the chemical composition of traditional and proposed plant components of the cutlet mixture.
2. Calculate the recipe composition of the cutlet mixture in order to increase its nutritional value.
3. Determine the method of preparing brewers' grains for use in the cutlet mixture.
4. To produce experimental samples of minced products using brewers' grains.
5. To compare the chemical composition of traditional and proposed minced products and determine the effectiveness of introducing secondary grain raw materials such as brewers' grains and whey to increase the nutritional value of protein dishes.

Research materials and methods

In the course of the work, a set of theoretical and analytical methods was applied to study the possibilities of forming a cutlet mass as a multicomponent food system. The methods used provided a systematic assessment of the chemical composition of the ingredients, their nutritional value, and their potential for inclusion in the recipe model.

The food density index (FDI) for individual nutrients was determined as a measure of the satisfaction of the daily physiological need for a particular nutrient under conditions where the individual's energy basket (2000 kcal) is filled only with the product under study (Method of calculating the food density index according to Drevnovsky).

The calculation was performed using the formula:

$$FDI = \frac{C \cdot M}{R} \cdot 0{,}01, \qquad [1]$$

where

C – nutrient content in 100 g of product;

M – amount of product providing 2000 kcal;

R – recommended daily intake of nutrient.

The calculation was performed for protein, fiber, fat, carbohydrates, ash, and B vitamins (B_9, B_6, B_{12}).

Calculation assumptions. When calculating nutritional value, the following assumptions were made, which correspond to the generally accepted methodology of nutritional research:

1. The daily energy requirement of a typical individual is 2000 kcal, which corresponds to the average value for the adult population according to WHO recommendations and international dietary protocols.
2. The chemical composition of the ingredients is considered constant, i.e., the average values given in the reference tables (protein, fat, carbohydrates, fiber, ash, B vitamins) were used.
3. Nutrient losses during cooking were not taken into account in the calculations, with the exception of a separate analysis of thermolabile components (B vitamins), which is mentioned in the discussion of the results.
4. The mass of the product for filling the calorie basket (M) is determined based on the actual energy value of the samples studied (kcal/100 g), which ensures a correct comparison between different recipe components.
5. The ratio of nutrients in a multicomponent system is considered additive, i.e., the total nutrient content in the cutlet mass is determined by the sum of the contributions of each ingredient, taking into account its mass fraction.
6. The food density index is assessed independently for each nutrient, which allows determining the degree of balance of the product according to various components.

No adjustments were made to the bioavailability calculations, as such an assessment requires separate experimental methods and goes beyond the scope of the tasks set.

These assumptions made it possible to standardize the calculations, ensure the comparability of indicators, and guarantee the reproducibility of the methodology.

The total fat content was determined in accordance with DSTU ISO 1443:2005 (MEAT AND MEAT PRODUCTS. Method for determining the total fat content (ISO 1443:1973, IDT)).

The total protein content was determined in accordance with DSTU ISO 937:2005 (MEAT AND MEAT PRODUCTS. Determination of nitrogen content (control method), (ISO 937-1978, IDT)).

The moisture and dry matter content was determined in accordance with DSTU ISO 1442:2005 (MEAT AND MEAT PRODUCTS. Method for determining moisture content (control method) (ISO 1442:1997, IDT)).

The fiber content was determined in accordance with DSTU EN ISO 6865:2022 (Animal feed. Determination of crude fiber content. Method with intermediate filtration (EN ISO 6865:2000, IDT; ISO 6865:2000, IDT)).

Results of the research and their discussion

The information search showed the feasibility of improving the recipe composition of the cutlet mass, which we implemented using the example of minced chicken products. Barley brewers' grains were selected as a source of plant proteins and dietary fiber, and their chemical composition was studied in comparison with wheat bread. First of all, we were interested in how many macronutrients are contained in this secondary plant raw material. The results of the research are presented in Table 1.

Recalculation of the macronutrient content in dry matter in wheat bread and brewers' grains showed that wheat bread is a carbohydrate food product, while brewers' grains are a protein product with a high fiber content. The protein content in brewers' grains is 1.75 times higher than in wheat bread, while the mass fraction of carbohydrates in brewers' grains is 1.78 times lower than in wheat bread. Even more impressive is the fiber content, which is four times higher in brewers' grains than in wheat bread.

The patterns are more clearly illustrated by the calculation of food density indices (FDI), which take into account the presence of nutrients in a product in accordance with its caloric content [10]. It has been established that brewers' grains contain significant amounts of protein, fiber, and mineral compounds, and the food density indices of these nutrients significantly exceed the recommended intake. The food density indices of protein and fiber in wheat bread are less than one, which indicates their insignificant content compared to the recommended intake.

The results show that brewers' grains can be considered a source of vegetable protein and used in combination with animal protein to form cutlet mass. At the same time, the multicomponent system will be significantly enriched with fiber, which will contribute to better absorption of amino acids in the human body [1].

The absorption of the amino acid methionine without the formation of homocysteine is also influenced by the presence of B vitamins in a multicomponent system [11]. Therefore, we calculated the nutritional density indices of folic acid (B9) and vitamins B6 and B12 for possible ingredients of a multicomponent system. We took into account the recommended daily intake of these vitamins for most people: folic acid – 400 mcg, vitamin B6 – 1.3–1.7 mg, vitamin B12 – 2.4 mcg. The results of the calculations are shown in Table 2.

The ambiguity of the data shows that only eggs are a product that contains sufficient amounts of these vitamins. Even chicken mince has been found to be deficient in folic acid. Plant-based raw materials are known to contain no vitamin B12. Whey is rich in vitamins B6 and B12, but its folic acid content is less than one unit.

Thus, it has been shown that a multicomponent system can be formed in such a way that its chemical composition will correspond to the recommended values for the content of functional ingredients.

The technology for producing minced meat products in catering establishments has certain differences compared to the industrial production of natural semi-finished products, which is due to the specifics of production conditions, speed of service, and requirements for product quality stability. Similar differences are noted in scientific and technological sources on meat processing [3, 6].

The cutlet mass is obtained by grinding meat raw materials in a meat grinder with the addition of auxiliary components - sodium chloride, ground black pepper, and water in an amount of 5-8% of the meat mass. This technological approach is described in detail in studies of modern meat mince systems [3]. Onions, which serve as an aromatic and flavor-enhancing ingredient, can be used raw or sautéed. According to Maikova et al. [3], sautéed onions can intensify the meat aroma of finished products. Nutmeg or cardamom are used as additional flavorings.

Table 1. Average chemical composition and nutritional density index of brewers' grains and wheat bread

Product	Composition, % on a dry basis				
	Protein	Carbohydrates	Fiber	Fat	Ash
Wheat bread	12	78	5	2	3
Brewers' grains	21	44	20	8	7
	The food density index (FDI)				
Wheat bread	0.9	1.3	0.9	0.6	1.3
Brewers' grains	2.0	0.9	6.0	0.7	2.2

Table 2 – Food density indices of certain B vitamins in probable ingredients of cutlet mixture

Food product	Food density indices		
	Folic acid (B9)	Vitamin B_6	Vitamin B_{12}
Minced chicken	0.1	3.6	2.6
White bread	2.1	0.3	0.0
Brewers' grains	0.5	1.8	0.0
Whey	0.5	1.8	4.9
Chicken eggs	1.6	1.0	6.0

To obtain minced semi-finished products, meat raw materials, high-grade wheat bread, onions, garlic, spices, milk or water, and breadcrumbs are used. Traditionally, bread is added in an amount of 17-25% of the meat mass, the liquid phase is within 30%, and the meat component accounts for 50-55%. According to [3], wheat bread acts as a moisture-retaining filler and provides the necessary rheological characteristics of minced meat - adhesion, cohesion, and structural stability. In industrial conditions, as stated in [3], modified starches, flour, or crushed cereal products can be used as additional moisture-retaining components.

Modern technological techniques allow for variations in the structure of minced meat: part of the meat can be minced by hand, while the rest can be turned into a puree-like mass, which allows for a pronounced textural contrast. The use of spices (marjoram, cloves) and the addition of alcohol-containing ingredients (wine, brandy, liqueurs) for flavoring is in line with trends in the formation of the taste and aroma profile of meat dishes [3]. Aging the minced meat for 1-2 hours at 2...4 °C increases its moisture-binding capacity, which has been confirmed in studies on the rheology of food systems [6].

For public catering, heat treatment of formed fried minced meat products is carried out in heated fat at a temperature of 150...160 °C. The heat treatment is completed in an oven at 250...270 °C for 5-7 minutes. The core temperature of the product should be 85 °C for natural minced products and 90 °C for meat and vegetable products. During heating, meat proteins undergo thermal coagulation, accompanied by compaction of muscle fibers, a decrease in their diameter, the release of moisture into the interstitial space, swelling, and partial hydrolytic destruction of collagen fibers [5, 6]. Hydrothermal decomposition of collagen in gluten occurs at 60...64 °C, which causes the meat to soften and increases the ability of protein-collagen structures to retain moisture [5, 6].

Stale white bread, which is added to the recipe for classic meat cutlets, and brewers' grains in the proposed technology for making cutlet mass can also be considered as fillers that affect the consistency of food products. As is known [7], fillers are inexpensive food raw materials used to regulate the mass and volume of food products. Recently, this technological approach has been considered as an opportunity to reduce the calorie content of food products. Fillers are used to compensate for the loss of mass and volume of a product when its fat, sugar, and other carbohydrate content is reduced.

In addition, fillers cause a feeling of satiety without adding extra calories to the diet. The most important fillers are starches, various types of cellulose, etc. While starch is the main consistency regulator in white bread, the carbohydrate content in brewers' grains is significantly reduced due to the peculiarities of the technological process, while the mass fraction of fiber has increased significantly.

As a result of the analysis, several recipe options were developed, from which a ratio of ingredients was selected that did not lead to a deterioration in the nutritional value and organoleptic characteristics of the finished product. The final recipe for the cutlet mixture is shown in Table 3.

Table 3 – Cutlet mixture recipe

Food ingredient	Mass fraction, %
Minced chicken	61.0
Brewers' grains	7.0
Milk whey	24.0
Chicken eggs	6.0
Salt	1.0
Pepper	1.0

Figure 1 shows a flow chart for the preparation of chicken cutlets with the addition of brewers' grains powder hydrated in whey, indicating critical control points in the product manufacturing process.

The implementation of these critical control points (CCPs) in the technology is based on the principles of the HACCP system and takes into account the key biological, chemical, and physical risks associated with the production of semi-finished meat products [16, 17]. The addition of brewer's yeast powder hydrated in whey requires special attention to temperature and time regimes, as this ingredient is a rich medium for the growth of microorganisms. Control at the stages of its hydration, mixing, and further processing ensures the stability of the quality and safety of finished products. CCPs related to the processing of eggs and meat raw materials are aimed at preventing primary and secondary contamination with pathogens [18,19]. Heat treatment is a key point that guarantees the reduction of microbiological risks to an acceptable level in accordance with food safety requirements.

The consistency of the cutlet mass is characterized by such indicators as cohesion (bonding) or interaction of molecules, atoms, ions within one phase, and adhesion, as the molecular attraction of heterogeneous solid phases that come into contact. Also, during the production of cutlet mass, a set of phenomena or wetting occurs at the boundary of three phases.

The effect of brewers' grains on the consistency of minced meat can be determined by changes in the organoleptic properties of semi-finished or finished products, as well as by studying their physical and chemical properties. The results of studies of these properties of minced meat and finished cutlets are presented in Tables 4 and 5, respectively.

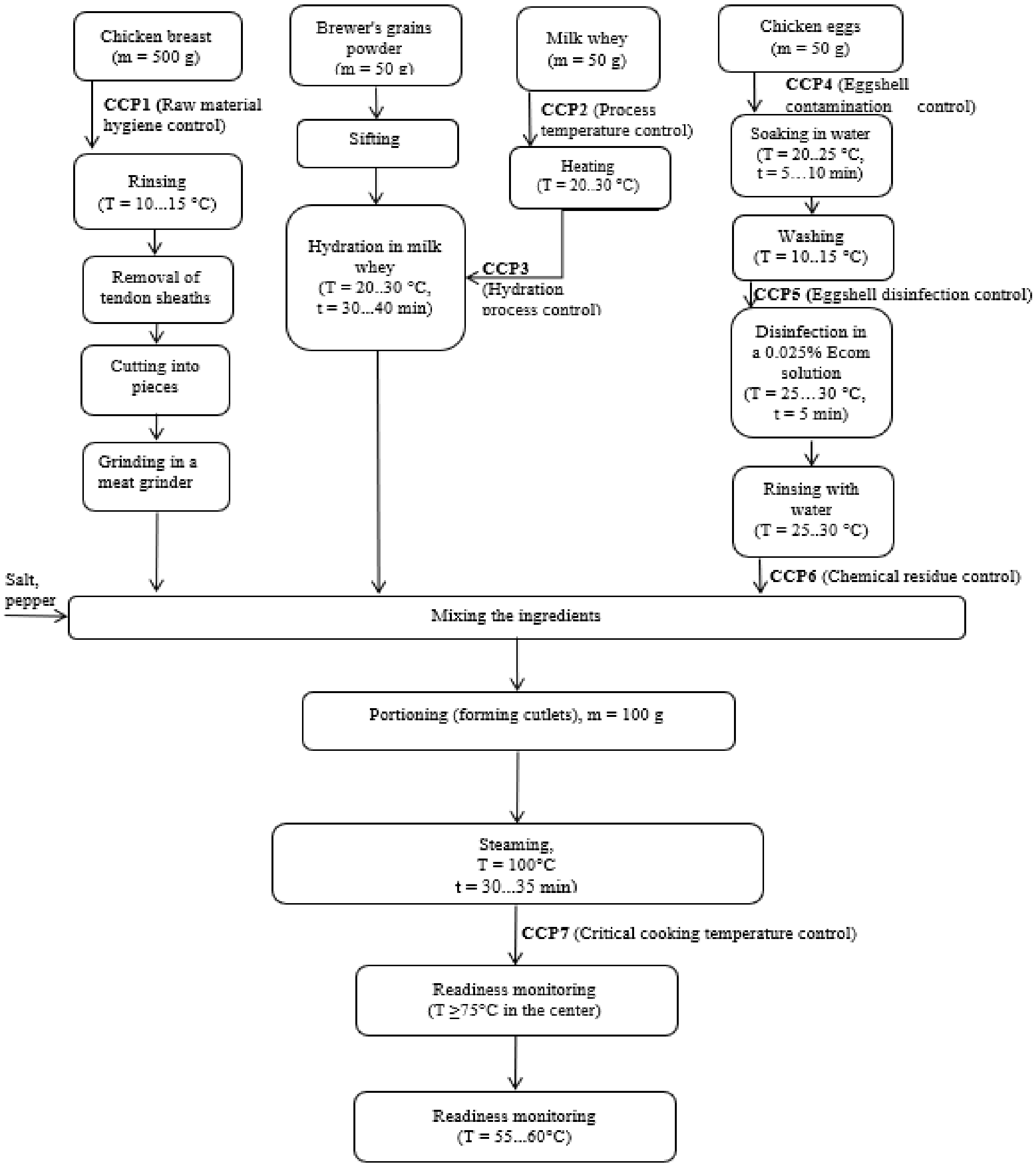

Fig. 1 - Technological scheme for preparing chicken cutlets with the addition of brewers' grains powder hydrated in whey

Table 4 - Results of studies of the physicochemical indicators of minced semi-finished products (minced meat) from chicken meat with the addition of powder brewers' grains pre-hydrated in whey

№	Indicator name	Measurement results, %	Uncertainty, U (k=5, P=0.05)
1	Mass fraction of dry matter, including:	38.35	± 0.45
	Mass fraction of total protein	17.25	± 0.125
	Mass fraction of total fat	12.10	± 0.15
	Mass fraction of fiber	5.68	± 1.45
	Mass fraction of other dry matter (carbohydrates, minerals, etc.)	3.32	± 0.1
2	Mass fraction of moisture	61.65	± 0.425

Table 5 - Results of studies of the physicochemical indicators of ready-made chicken cutlets with the addition of powder brewers' grains pre-hydrated in whey

№	Indicator name	Measurement results, %	Uncertainty, U (k=5, P=0.05)
1	Mass fraction of dry matter, including:	37.61	± 0.30
	Mass fraction of total protein	17.12	± 0.075
	Mass fraction of total fat	12.88	± 0.15
	Mass fraction of fiber	5.54	± 1.38
	Mass fraction of other dry matter (carbohydrates, minerals, etc.)	2.07	± 0.1
2	Mass fraction of moisture	62.39	± 0.30

Studies of the physical and chemical characteristics of minced meat have shown that the addition of brewers' grains powder, pre-hydrated in whey, affects the components of the recipe system, while keeping all indicators within the normative values characteristic of combined minced poultry semi-finished products.

The mass fraction of dry matter was 38.35%, which is significantly higher than the average values for minced meat without plant additives. This value is due to the addition of brewer's grains, rich in plant protein, fiber, and other dry components, as well as the ability of hydrated fibers to retain part of the moisture in a bound state.

The protein content in the minced meat was 17.25%, which demonstrates a combination of meat proteins and additional protein fractions obtained from hydrated brewers' grains and whey. The mass fraction of fat was 12.10%, which corresponds to the normative values for chicken mince and indicates that the additional plant raw materials did not cause its dilution. The fiber content of 5.68% further confirms that brewer's grains are a source of dietary fiber and act as a functional ingredient that can improve the texture and water-holding capacity of meat systems.

The mass fraction of other dry substances was 3.32%, indicating the presence of carbohydrates, minerals, and other low-molecular components, partially added with whey. The mass fraction of moisture in the minced meat was 61.65%, which corresponds to the normative values for minced semi-finished products with plant fibers and indicates a rational level of hydration of plant additives.

After steam heat treatment, insignificant but regular changes in the physicochemical composition of the finished product were determined, caused by heat treatment.

The mass fraction of dry substances in the finished cutlets was 37.61%, while in minced meat this indicator was higher (Table 4). This indicates the formation of a more stable protein-polysaccharide gel structure capable of retaining more moisture in a bound state under conditions of thermal coagulation of proteins and swelling of fiber.

The protein content in the finished product was 17.12%, which indicates high stability of protein components under the influence of temperature. Only a small part of the soluble protein fractions could transform into thermally modified forms, which explains the minimal difference between the raw and finished systems.

The mass fraction of fat in the cutlets increased to 12.88%, which is a typical trend for heat-treated meat products. The increase in the relative proportion of fat is associated with a partial loss of moisture during frying and the retention of lipids by the fiber of the brewers' grains, which prevents excessive fat melting.

The fiber content in the finished cutlets was determined to be 5.54%, which practically corresponds to the initial value in the minced meat (Table 4). This confirms the heat resistance of dietary fibers and their stability in the structure of the finished product. The mass fraction of other dry substances decreased to 2.07%, which may be associated with the loss of some water-soluble components during heat treatment.

The moisture content of the finished cutlets was 62.39%, which is slightly higher than in minced meat. This result may be due to the water-retention properties of fiber and proteins, which, after thermal denaturation, form a structure capable of retaining moisture more effectively.

A comparison of the two systems allows us to determine the nature of the effect of heat treatment on meat and vegetable products. The mass fraction of dry matter in cutlets is slightly lower at 37.61%, while for minced meat this figure is 38.35%, which indicates a redistribution of moisture and the formation of a denser system after heat treatment. The protein content has also decreased slightly, confirming the stability of the protein component and insignificant losses during heat treatment.

The relative increase in the mass fraction of fat in cutlets is a result of moisture evaporation and fat fraction concentration in the finished product. The fiber content in cutlets remains virtually unchanged, which proves the structural stability of the fibrous fraction even during high-temperature processing.

The most pronounced changes are observed in the mass fraction of other dry substances: a decrease from 3.32% to 2.07% may be associated with the diffusion and loss of water-soluble components during heat treatment. At the same time, the mass fraction of moisture increases from 61.65% to 62.39%, which indicates the formation of a structure with increased water retention capacity caused by the swelling of cellulose and coagulation of proteins, which create a stable gel matrix.

The resulting cutlets have a rich chemical composition and are characterized by a high food density index (Table 6).

Table 6 - Average chemical composition and nutritional density index of the developed cutlets

Product	Composition, % on a dry basis				
	Protein	Carbohydrates	Fiber	Fat	Ash
Classic chicken cutlets	45	28	0.7	25	1.3
Cutlets with brewers' grains	62	19	6.8	8	4.2
Food density index (FDI)					
Classic chicken cutlets	2.7	0.4	0.3	1.4	0.7
Cutlets with brewers' grains	5.1	0.3	1.7	0.6	1.4

We also calculated the nutritional density indices for folic acid (B9) and vitamins B6 and B12 for cutlets made according to the classic recipe and for cutlets with brewers' grains. The results of the calculations are shown in Table 7.

Table 7 – Food density indices of certain B vitamins in chicken cutlets

Food product	Food density indices		
	Folic acid (B9)	Vitamin B_6	Vitamin B_{12}
Classic chicken cutlets	0.4	3.9	1.1
Cutlets with brewers' grains	0.5	4.6	3.2

The data shows that cutlets made according to the classic recipe are slightly inferior to similar indicators in the developed cutlets in terms of B vitamin content, but these fluctuations are insignificant. According to the food density index for folic acid, it can be said that its content in the products does not allow the daily intake requirement to be met. In addition, during intense heat treatment, this vitamin can be destroyed by almost 90%. Therefore, to ensure folic acid in the diet, it is sufficient to serve cutlets with a side dish and greens, which are a source of folic acid. For example, the food density indices for vitamin B9 (folic acid) for various types of greens are as follows: parsley – 21.0; lettuce – 13.0; celery – 11.0; spinach – 12.0; beetroot – 12.0.

The results confirm the effectiveness of using brewers' grains as a functional ingredient in a multi-component cutlet mixture. A comparative analysis of the chemical composition of the raw materials showed that brewers' grains significantly exceed traditionally used wheat bread in terms of protein, fiber, and ash content, which correlates with high nutritional density index values for these nutrients. The increase in the nutritional density index of protein and fiber in the developed recipe confirms the promise of replacing bread filler with a plant protein fraction with increased nutritional value.

The results of physical and chemical studies show that adding brewers' grains hydrated in whey not only increases the dry matter content in minced meat, but also improves the rheological characteristics of the meat system due to its developed fibrous structure and the ability of fiber to retain moisture and fat. A comparison of the composition of minced meat and ready-made cutlets showed minimal protein loss and preservation of the fiber structure after heat treatment, which confirms the technological feasibility of using this ingredient under high-temperature conditions.

The increase in the nutritional density indices of B vitamins in cutlets with brewers' grains is explained by the combined action of eggs and whey, but the insufficient level of NDI for folic acid is consistent with the literature data on its thermolability and low content in ingredients of animal origin. This indicates the need to combine such products with side dishes or greens rich in folates.

The increase in the water-holding capacity of finished products, recorded in the analysis, also corresponds to the data of previous studies on the hydrophilic properties of plant fibers and milk proteins.

Thus, the complex of data obtained indicates that the introduction of hydrated brewers' grains not only increases the nutritional value and food density index of the cutlet mass, but also improves its structural and mechanical properties, ensuring the density of the meat system and high organoleptic indicators. This confirms the promising use of secondary grain raw materials in the recipes of modern meat and vegetable products with an emphasis on healthy and rational nutrition.

Conclusion

Theoretical and experimental studies have shown that when forming cutlet mass, in order to improve the composition of the multicomponent system, it is possible to significantly improve the chemical composition and quality indicators of both the cutlet mass and the finished product itself. The use of dry brewers' grains as a filler, after their restoration in milk whey, allows increasing the mass fraction of protein, fiber, minerals, and some B vitamins. Products made from the developed cutlet mass have high organoleptic properties and improved economic efficiency due to the use of secondary raw materials, which confirms the effectiveness of using brewer's grains as a functional ingredient in minced meat products and makes it possible to create a food product with increased nutritional density, balanced nutrient composition, and improved rheological properties.

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ФОРМУВАННЯ КОТЛЕТНОЇ МАСИ ЯК ПОЛІКОМПОНЕНТНОЇ ХАРЧОВОЇ СИСТЕМИ

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Анотація. У статті розглянуто науково обґрунтований підхід до формування котлетної маси як полікомпонентної харчової системи з підвищеною харчовою щільністю. Актуальність роботи зумовлена потребою створення продуктів, що поєднують білки тваринного і рослинного походження та містять достатню кількість вітамінів, мінеральних речовин і харчових волокон. Проаналізовано хімічний склад традиційних компонентів котлетної маси та альтернативної рослинної сировини. Особливу увагу приділено пивній дробині як вторинному продукту переробки зерна, що містить значну кількість білка, клітковини та мінеральних речовин. Порівняльні дослідження показали, що пивна дробина істотно перевищує пшеничний хліб за вмістом білка та клітковини, що робить її цінним функціональним інгредієнтом. На основі теоретичного та аналітичного опрацювання даних сформовано рецептуру котлетної маси з використанням курячого філе, пивної дробини, яєць та молочної сироватки. Проведено розрахунок харчової цінності отриманих зразків та визначено індекси харчової щільності основних нутрієнтів, включаючи білки, жири, вуглеводи, харчові волокна та вітаміни групи В. Встановлено, що введення пивної дробини сприяє підвищенню частки рослинного білка, збагаченню продукту клітковиною та покращенню засвоєння амінокислот завдяки наявності вітамінів групи В у яєчних та молочних інгредієнтах. Досліджено технологічні особливості отримання котлетної маси, включаючи підготовку сировини, змішування компонентів, вплив рослинної клітковини на консистенцію та здатність системи утримувати вологу і жир. Наукова новизна полягає у встановленні функціональної ролі пивної дробини як текстуроутворювача та водозв'язувального компоненту у структурі м'ясного виробу при її попередньому гідратаційному модифікуванні. Практичне значення дослідження полягає у можливості використання пивної дробини як доступного білково-волокнистого інгредієнта у виробництві м'ясних продуктів із покращеними технологічними та споживчими характеристиками при одночасному зниженні собівартості. Основні висновки дослідження свідчать про доцільність використання порошкоподібної пивної дробини, гідратованої у сироватці, як ефективного компонента рецептури для підвищення якості січених м'ясних виробів.

Ключові слова: полікомпонентні системи, котлетна маса, пивна дробина, молочна сироватка, індекс харчової щільності