QUBAHAN ACADEMIC JOURNAL
VOL. 4, NO. 4, October 2024
https://doi.org/10.48161/qaj.v4n4a264

The Role of Mechanical Mixing and Biologically Active Additives in Enhancing Cutlet Quality

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ABSTRACT: The research relevance is determined by the need to understand the effect of mechanical mixing and the use of biologically active additives on the quality of cutlet mass, which will optimize food technologies and create products with improved texture and nutritional value. This need stems from the fact that the quality and characteristics of culinary products are important criteria for consumers. The research aims to investigate the relationship between mechanical mixing parameters and the use of biologically active additives with structural and mechanical quality parameters of cutlet mass, to improve production processes and develop higher quality food products. Analytical methods, classification methods, functional methods, statistical methods, and synthesis methods were used to determine the quality of the cutlet mass. In the course of the study, a comprehensive analysis of the effect of various parameters of mechanical mixing and the use of various biologically active additives on the structural and mechanical characteristics of the cutlet mass was carried out. It was found that optimal mixing conditions and types of additional components can significantly improve the textural properties of the product. It was found that the use of certain biologically active additives helps to increase the resistance of the mass to mechanical stress and preserve its juiciness. These conclusions allow us to develop more effective strategies for the production of cutlet mass with improved quality and nutritional value. The practical significance of this study is to provide scientifically based recommendations for optimizing food production processes aimed at improving the quality and nutritional value of cutlet mass by studying the effect of mechanical mixing and biologically active additives on its structural and mechanical properties.

Keywords: food technology, texture, nutritional value, consumer demand, innovations in the food industry.

I. INTRODUCTION

The research is of great practical and scientific importance for the food industry and the scientific community. Optimization of food production processes, in particular cutlet mass, is a key aspect in providing high-quality and balanced food products for consumers. The study of the effect of mechanical mixing and the use of biologically active additives on the structural and mechanical properties of cutlet mass will allow the development of optimal production technologies that will improve its texture and taste and preserve important nutrients. This research will contribute to the scientific understanding of the processes that occur during the mechanical processing of food and the interaction of components in them. The study of structural changes at the molecular level and the effect of additives on these processes will help enrich fundamental knowledge in the field of food science. This can open the door to new opportunities for the development of innovative products with improved characteristics that meet modern consumer requirements for food safety and quality.

The research focuses on the relationship between the structural and mechanical quality indicators of cutlet mass and the effect of mechanical mixing and biologically active additives. One of the main difficulties is the lack of understanding of the optimal mixing parameters and their impact on the structural properties of the product. A need to clarify the impact of different types of biologically active additives on the quality and

structure of the cutlet mass is also needed. Clarification of these aspects is important for the development of optimal food technologies and the manufacture of products that meet consumer requirements for quality, taste, and nutritional value.

According to N. Bondar et al. [1], the study of structural changes in cutlet mass indicates the complex nature of this process, which is due not only to mechanical mixing but also to the use of specific biologically active additives. Despite the available results, the study has not yet sufficiently investigated the specific effect of various biologically active additives on the mechanisms of structural changes in cutlet mass and their interaction with other components. In addition, the effect of these additives on the quality characteristics of the final product, such as fluidity, density, and structural integrity, has not yet been considered in detail. S.V. Ivanov et al. [2] emphasize that the regulation of the structural and mechanical properties of low-calorie cut meat semi-finished products using nanocomposites can open up prospects for creating products with improved texture and consistency, providing the desired consumption experience with reduced calorie content. Additional research could be aimed at studying the effect of different types of nanocomposites on the structural and mechanical properties of low-calorie cut meat semi-finished products to optimize their quality and suitability for consumption.

According to V. Burak and N. Novikova [3], a Hazard Analysis Critical Control Point (HACCP) is key to ensuring quality and safe food products. It allows to achievement of optimal technological settings in the production process, which contributes to compliance with safety and quality standards. O.S. Kabat et al. [4] emphasize the importance of optimal selection of mechanical mixing parameters since insufficient or excessive influence on this process can adversely affect the structure and consistency of the final product. However, the influence of these parameters on specific aspects of structural changes, as well as their relationship with the use of biologically active additives, remains insufficiently studied. According to N.M. Sonko et al [5], consideration of the interaction between mechanical mixing and biologically active additives highlights the importance of this aspect in the development of innovative methods for the production of cutlet mass with improved quality and nutritional value. However, there is still a lack of understanding of the interaction between specific biologically active additives and mechanical effects on their properties and impact on product structure.

The research aims to analyses the relationship between the parameters of mechanical mixing and the use of biologically active additives in the context of the structural and mechanical characteristics of cutlet mass. Furthermore, this study aimed to improve production processes and develop higher-quality food products with improved quality. The main research question appears to be: How do mechanical mixing parameters and biologically active additives influence the structural and mechanical quality indicators of cutlet mass? The authors' hypothesis is: mechanical mixing parameters and biologically active additives impact cutlet mass quality.

Key objectives include:

1. Analyzing the relationship between mechanical mixing parameters, biologically active additives, and cutlet mass quality.
2. Determining optimal mixing conditions and additive combinations to improve product texture and nutritional value.
3. Developing scientifically-based recommendations for optimizing cutlet production processes.

The study's original contributions are new insights into the influence of mechanical mixing parameters and biologically active additives on the structural and mechanical properties of cutlet mass. It establishes optimal ranges for key quality indicators such as moisture content, tenderness, shear strength, and viscosity. Additionally, the study demonstrates the synergistic effects of combining mechanical mixing with biologically active additives to improve product quality. A new formulation is developed that incorporates antioxidant components, such as butter, Biovit, and mint or thyme powder, to enhance both the quality and nutritional properties of the cutlet. The general research framework is presented on Figure 1.

Literature Review and Hypothesis Formulation	A comprehensive review of existing literature will be conducted to understand the current state of knowledge on mechanical processing, the role of biologically active additives, and their combined effects on food product quality. The hypothesis of the study is that optimizing mechanical mixing parameters and the inclusion of biologically active additives will significantly enhance the structural and mechanical quality indicators of cutlet mass.
Experimental Design	The research will employ a factorial experimental design, allowing for the investigation of multiple factors, including the intensity and duration of mechanical mixing and the type and quantity of biologically active additives. Each factor will be tested across a range of levels to determine its individual and interactive effects on the quality of the cutlet mass.
Sampling and Material Selection	A purposive sampling method will be used to select specific ingredients and additives based on their potential to improve the quality of cutlet mass. The selection criteria will include prior research, theoretical considerations, and practical applicability in food production.
Data Collection	Data will be collected through a series of controlled laboratory experiments. Measurements will include structural and mechanical properties such as texture, moisture retention, pH, and shear strength. Instruments like texture analyzers, pH meters, and moisture analyzers will be employed to ensure precise and reliable data collection under standardized conditions.
Data Analysis	Statistical methods will be used to analyze the data, focusing on establishing significant relationships between mechanical mixing parameters, the inclusion of biologically active additives, and the resulting quality of the cutlet mass. The analysis will identify optimal conditions for mixing and additive inclusion that yield the highest quality product.
Theoretical Framework	The study is grounded in food science and technology theories, with a focus on mechanical processing, the role of biologically active additives, and quality optimization. This framework guides the investigation of the interactions between processing methods, ingredient composition, and the final product's structural and mechanical properties.
Discussion and Interpretation	The results will be discussed in the context of existing literature, with a focus on how the findings contribute to the current understanding of food product development. The implications of the study for optimizing food production processes and improving product quality will be explored.
Conclusion and Recommendations	The study will conclude by summarizing the key findings and their implications for the food industry. Recommendations will be provided for further research and practical applications in food production, focusing on the development of high-quality, nutritionally enhanced products.

FIGURE 1. The research framework.

II. LITERATURE REVIEW

New-generation food product development has a number of issues that need an integrated strategy, especially in the area of mass-produced cutlets. With an emphasis on the impact of mechanical mixing and biologically active additives, this study summarizes recent findings on the structural and mechanical characteristics of cutlet mass.

According to U.E. Obianwuna et al. [6], adding protein supplements and plant materials with antioxidant qualities can greatly increase a product's ability to withstand oxidation and maintain its quality over an extended period of time. This is especially true for chopped items, which are a great way to add these kinds of ingredients. Based on the research, it appears that these modifications increase texture, taste, and scent in addition to increasing nutritional content.

S. Esteghlal et al. [7] discovered that heat treatment procedures might cause the direct degradation of amino acids, lowering their quantity and the biological value of the product. Their findings emphasise the need to establish optimal heat treatment procedures to preserve the largest number of amino acids while retaining the protein's biological usefulness. E. Herz et al. [8] discovered that increasing the amount of minced meat ground results in improvements in structure, viscosity, and stickiness, potentially improving the texture and consistency of finished products.

According to M.J. Santos et al. [9], only a few key ingredients with high protein content and optimal amino acid composition typically determine the protein quality of the finished product. Their work shows that culinary formulations are complex ingredient combinations where proteins from different products interact to form qualitatively new structures and flavour characteristics.

The substantial difficulties in supplying the human body with all required macronutrients and micronutrients through a regular diet in the current world were brought to attention by N.E. Marshall et al. [10]. Their findings highlight the significance of creating novel food products with higher nutritional content in order to potentially affect a number of physiological processes in the human body and enhance disease resistance. B. Hennchen [11] emphasised the importance of taking an integrated strategy while developing new-generation food items. This method takes into account market demand for creative products, the need to update assortments, assure efficient use of raw resources, and shorten the technological cycle of production, notably in the restaurant business.

The findings of N.K. Abilmazhinova et al. [12] and N. Omelchuk [13] emphasise the importance of antioxidants in meat products. Their research indicates that well-tailored antioxidant mixes can increase the nutritional value and durability of meat products, opening up new opportunities for product development in the food business.

This literature analysis demonstrates that mechanical processing, heat treatment, protein interactions, and the inclusion of bioactive chemicals all have a role in determining cutlet mass quality. The findings imply that an integrated approach, taking into account both processing methods and component composition, is critical for generating high-quality, nutritionally enhanced food items that match modern consumer needs.

Building on the insights gained from the reviewed literature, this study hypothesizes that the parameters of mechanical mixing and the inclusion of biologically active additives have a significant impact on the structural and mechanical quality indicators of cutlet mass. Specifically, it is proposed that optimizing these parameters will lead to improvements in texture, moisture retention, and overall product quality.

III. MATERIAL AND METHOD

1. RESEARCH DESIGN

The research design for this study was primarily experimental. The research employed a factorial design to systematically investigate the structural and mechanical properties of cutlet mass under various conditions. This design allowed for the exploration of multiple factors, such as the intensity and duration of mechanical mixing and the inclusion of biologically active additives, and their interactions on the final product quality. The study aimed to systematically analyse the relationships between processing parameters, additive inclusion, and final product quality. Choosing this design allowed to isolate the effects of individual variables while also examining potential synergistic interactions between them. The experimental setup was structured, with each factor being tested across a range of levels to determine its influence on key quality indicators, such as moisture retention, tenderness, and shear strength. This approach ensured that the findings could provide robust insights into the optimization of food production processes.

2. SAMPLING

The study has used a purposive sampling method, selecting specific ingredients and additives based on their potential to improve cutlet mass quality. The selection criteria were based on a combination of prior research findings, theoretical considerations, and practical applicability in food production. Ingredients like soy protein products, milk powder, and a variety of dried spices were chosen due to their documented effects on improving texture, moisture retention, and overall nutritional value. The choice of biologically active additives, such as mint and thyme powder, was driven by their antioxidant properties and ability to enhance the organoleptic qualities of the final product. All of it allowed the study to focus on ingredients with the highest potential impact.

3. DATA COLLECTION

The data collection was carried out through a series of laboratory experiments. The analytical method was employed to thoroughly study the structural and mechanical properties of the cutlet mass. This involved systematic analysis and comparison of results from various experiments, allowing for the determination of optimal mixing conditions and suitable additives. Specific measurements included moisture content, pH, moisture retaining capability, tenderness, maximum shear stress, plastic viscosity, and plasticity. These measurements were taken under standardized conditions, with the temperature and humidity carefully controlled to ensure consistency across all experiments [2, 3]. Specific protocols were established to standardize the mixing process, such as maintaining a consistent mixing speed and duration for each batch, thereby minimizing variability. Controls were implemented to compare the effects of the biologically active additives against a baseline recipe [8].

4. VARIABLES AND MEASURES

The study considered several variables. Independent variables included the parameters of mechanical mixing (such as intensity and duration) and the types and quantities of biologically active additives used. Dependent variables were the structural and mechanical properties of the cutlet mass, including its resistance to mechanical stress and textural quality. The functional method was used to study the effect of various biologically active additives on the physical, chemical, and organoleptic characteristics of the product. The structural-functional method was employed to examine the relationship between structural features and functional characteristics of the cutlet mass at different levels of the product's molecular structure.

5. DATA ANALYSIS

For data analysis, the study utilised statistical methods to evaluate the effect of various parameters of mechanical mixing on the structural and mechanical properties of the cutlet mass. This allowed for the establishment of statistically significant relationships between the intensity of mixing, the duration of processing, and product quality.

The deduction method was used to systematically study the cause-and-effect relationships between various factors affecting the quality of the cutlet mass. The synthesis method was applied to introduce innovative approaches to optimise the structural and mechanical characteristics of the cutlet mass, leading to the development of specialised formulations with precisely selected biologically active additives.

6. THEORETICAL FRAMEWORK

This research is based on food science and technology theories, namely those linked to food product development and quality enhancement. The theoretical framework is founded on three major pillars: mechanical processing, biologically active additives, and product quality optimization.

Mechanical processing. The study investigates the effects of mechanical mixing on the structural and mechanical properties of cutlet mass. This concept is based on rheological theories, which describe how mechanical forces influence food texture and consistency.

Biologically active additives. The study investigates the role of various additions, such as proteins, antioxidants, and plant-based ingredients, in improving the nutritional content and quality of cutlet mass. This approach is based on nutritional science and food chemistry principles.

Quality optimization. The framework encompasses the concept of synergistic interactions between mechanical processes and additives in order to attain optimal product quality. This idea is based on systems thinking in food product creation.

Building on these conceptual foundations, the study provides a series of interconnected ideas to drive the investigation. First, it proposes that optimizing mechanical mixing settings can considerably increase the homogeneity and stability of cutlet mass structures. This optimization process is inextricably related to the use

of biologically active chemicals, which are believed to improve moisture retention and softness. The framework also proposes a synergistic relationship between mechanical processing and additive inclusion, arguing that combined optimization might result in higher structural and mechanical properties in the final product. This synergy includes the development of antioxidant-rich components, which are believed to improve both quality and nutritional qualities. Finally, the study suggests that careful modulation of protein sources, together with proper mechanical processing and additive inclusion, can result in enhanced amino acid profiles and overall protein quality in cutlet mass. This comprehensive approach to product development emphasizes the intricate relationship between processing methods, ingredient composition, and final product qualities in food science and technology.

This theoretical framework offers a systematic approach to studying the complicated interactions between processing methods, ingredient composition, and ultimate product quality in cutlet mass production. It lays the groundwork for empirical testing of these hypotheses and propositions, directing the research technique and data analysis processes.

IV. DATA ANALYSIS

The study of the influence of structural and mechanical indicators of cutlet quality on the characteristics of the mechanical mixing process and the use of biologically active additives is a key aspect of this study. The results obtained from the analysis of the interaction of these factors have the potential to open up new perspectives for optimizing technological processes and improving the quality of finished food products. In the context of the study, the main focus is on revealing the relationship between the parameters of mechanical mixing, the use of biologically active additives and the structure and mechanical characteristics of the cutlet mass, which is of particular importance in light of current trends. The information obtained during the implementation of this study can contribute to a deeper understanding of the factors affecting the quality of cutlet products and open up new opportunities for their practical use in the food industry.

The studies revealed that protein additives, such as milk powder and soybean products (soybean flour and soy texture), as well as dried spices and aromatics (pepper, parsley, rosemary, thyme, coltsfoot), have an impact on the structural and mechanical characteristics of fish cutlets. Table 1 presents the structural and mechanical quality parameters of fish cutlet mass prepared using different biologically active additives compared to a traditional recipe. The moisture content shows a slight decrease when biologically active additives are used, particularly with soybean flour and dry aromatics. The pH remains relatively stable but shows a slight increase towards alkalinity when soy protein products are used. Soybean products significantly enhance the moisture retaining capability of the fish cutlet mass compared to the traditional recipe and the recipe with milk powder. The tenderness improves with the inclusion of soybean products, especially with soybean flour. The maximum shear stress, which indicates the strength of the cutlet mass, increases with the addition of soybean products, indicating a stronger structure. The plastic viscosity decreases slightly with the addition of biologically active additives, indicating a smoother texture. Plasticity increases significantly with the use of soybean products, suggesting enhanced flexibility of the cutlet mass. The addition of soybean products (soybean flour and soy texture) significantly improves moisture retention, tenderness, maximum shear stress, and plasticity compared to the traditional recipe and the recipe with milk powder and aromatics. These improvements can be attributed to the functional properties of soy proteins, such as their ability to hydrate and swell. Figure 2 illustrates how moisture retention increases with longer mixing durations.

Table 1. Structural and mechanical quality parameters of fish cutlet mass with biologically active additives.

Indicators	Traditional recipe	With milk powder and aromatics	With soybean flour and dry aromatics	With soy texture and dry aromatics
Moisture, %	71.28±0.21	70.87±0.32	69.33±0.32	69.92±0.24
Environment, PH	6.81±0.01	6.8±0.02	6.88±0.02	6.96±0.01
Moisture retaining capability, %	45.1±0.21	43.5±0.14	50.4±0.32	52.1±0.6
Tenderness, cm2/g	241±10	251±10	275±2	263±11
Maximum shear stress, Pa	16.1±1	17.1±0.93	19.1±0.36	18.1±0.71
Plastic viscosity, Pa/s	15	14.6	14.3	14.4
Plasticity, s-1	72±2	83±2	100±7	100±1

[1] Source: compiled by the authors.

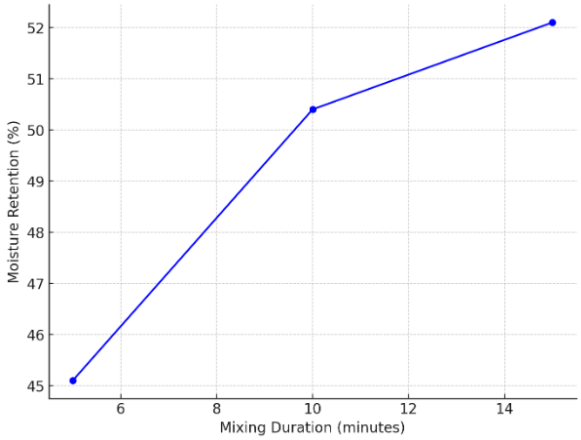

FIGURE 2. Relationship between mixing duration and moisture retention.

The research results show that replacing whole milk with milk powder has almost no effect on the moisture retention capacity of the cutlet mass. At the same time, soybean processing products significantly increase their moisture retention properties. In particular, the introduction of soy flour into the fishcake recipe increases the moisture content by 5.3% compared to the traditional recipe, and the introduction of soy texture even by 7%. This can be explained by the functional properties of soy proteins, such as their ability to hydrate and swell [14]. The pH of the medium is also an important factor: products with soy protein products have a pH deviation towards alkalinity (6.88±0.02 and 6.96±0.01, respectively).

A comparison of the pH and moisture retention capacity values shows that there is a relationship between the nature of the change in pH and the moisture retention capacity. An increase in moisture retention capacity simultaneously enhances the structure, as evidenced by a 14% increase in the ultimate shear stress with the addition of soy flour and a 9.1% increase in the addition of soy texture. It is important to note that the introduction of soy flour and soy texture also leads to an increase in the tenderness of the cutlet mass, which undoubtedly plays a role in improving the taste of the finished cutlets [15]. The main goal in the development of combined minced fish products is to identify compositions that provide a comprehensive therapeutic and prophylactic effect on the body, high antioxidant activity and excellent organoleptic quality characteristics. The task involves several stages. Based on the analysis of the medical and biological properties of individual antioxidants, a combination was selected that provides a comprehensive therapeutic and prophylactic effect on the human body. Figure 3 demonstrates the effect of different mixing conditions on plastic viscosity, with medium mixing conditions resulting in the lowest viscosity.

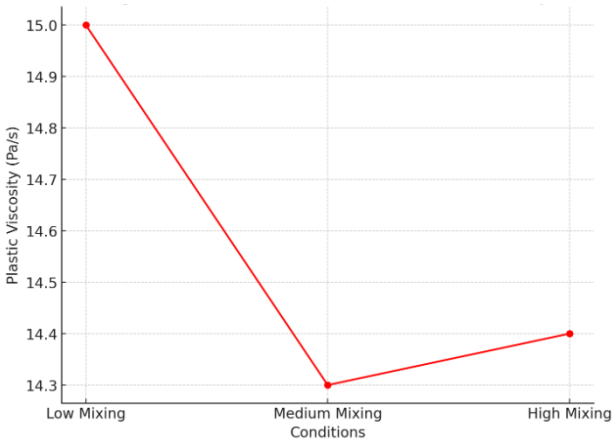

FIGURE 3. Combined effects on plastic viscosity.

Biological studies and clinical testing have shown that the combination of antioxidants with oak bark, thyme and red mountain ash has a significant effect on the body, providing a complex effect. Oak, thyme, and mountain ash cause a stimulating reaction in all components of the glutathione redox system: glutathione peroxidase activity (thyme, mountain ash), glutathione reductase activity (oak, thyme) and glutathione

transferase activity (mountain ash). In addition, thyme provides a high content of zinc ions, and oak bark contains a significant amount of potassium.

Combining an antioxidant with St. John's wort and thyme can be extremely beneficial, and it can play a significant role in maintaining health. St. John's wort, in particular, exhibits high total antioxidant activity, which helps the body fight stress and negative environmental influences [16]. This herbal component also stimulates glutathione reductase activity, an important enzyme that contributes to cell regeneration and protection. Thyme, on the other hand, adds extra weight to this combination. Its ability to boost glutathione peroxidase activity plays an important role in fighting harmful oxidation reactions in the body. In addition, thyme helps to increase the activity of glutathione reductase, which contributes to a more efficient functioning of the antioxidant system. It is especially important that thyme also includes zinc in its composition [17]. This trace element is of great importance for the body, as its deficiency is especially dangerous for children affected by the Chornobyl accident. Thus, the use of an antioxidant in combination with St. John's wort and thyme can help improve overall health and strengthen the body's defenses in the modern world. The antioxidants contained in coltsfoot and mint exhibit significant antioxidant activity, which makes it possible to use them in any formulation.

Some of the food ingredients in mixed minced fish products are known for their antioxidant effects, which play an important role in ensuring the quality and healthiness of these products. Among these ingredients are adaptogens, which include unrefined oil, parsley, dill, and garlic. They can effectively counteract free radicals and help increase the body's resistance to negative environmental influences. Plants rich in selenium make a particularly important contribution to antioxidant defense. Among them are soya and the Biovit product containing wheat germ flakes. These ingredients help to provide the body with selenium, which is a key antioxidant and has an important impact on the activity of various enzymes and metabolic processes. Additionally, herbal powders such as thyme and nettle are used in the formulation of combined minced fish products [18]. These herbs are noted for their positive effect on the immune system, which helps to increase the body's defenses. Moreover, they can act as adaptogens, stimulating physical and mental activity, and thereby contributing to the overall improvement of body functions. Products containing antagonist minerals or competitors for radionuclides also play a role in formulations. This includes Biovit wheat germ flakes and milk powder, which, together with other components, contribute to the sustainable antioxidant defense of the body and improve the quality of these products. Figure 4 compares the shear strength of cutlet mass with different biologically active additives, showing that soy protein results in the highest shear strength.

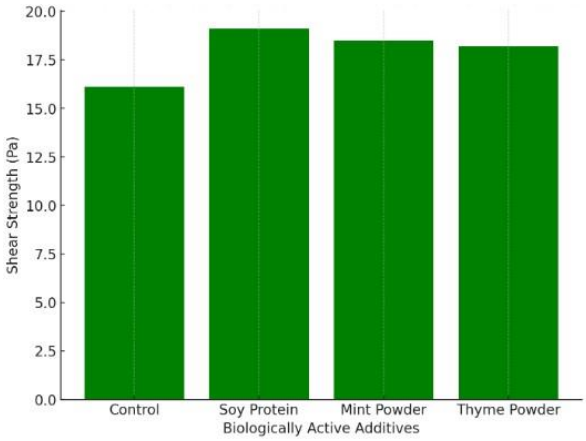

FIGURE 4. Comparison of Shear Strength with Different Biologically Active Additives.

Oxidative stress, which occurs intensively in all organs and tissues in the body and is especially intensified under conditions of negative environmental impact, is counteracted by an internal antioxidant defense mechanism that provides control over free radicals [19]. Bioantioxidants, naturally present in plants, can be used to activate this mechanism. Among them are phenolic compounds, flavonoids such as quercetin and runitol, as well as ascorbic acid, thyroid and steroid hormones, amino acids such as methionine, tryptophan, phenylalanine, as well as vitamins E and, A and carotenoids. Compounds such as tocopherols (vitamin E) and phenolic substances contribute to the known antioxidant properties of natural aromatic plants such as black pepper, cloves and mustard. By incorporating products containing vitamins E and C (such as Biovit, carrots, onions, and vegetable oil) into the formulation, the effectiveness of the antioxidant effect on the body can be

increased, as they interact synergistically. Vitamin E cooperates with selenium, as well as with vitamins A and β-carotene. These vitamins and minerals work together to help restore biological and morphological disorders in cellular and subcellular structures while increasing the sensitivity of red blood cells to peroxidative hemolysis [20, 21].

The simplex planning method was used to find the optimal composition of the compositions [13, 22]. This approach is extremely effective in conditions where many components need to be considered, as it is characterised by a minimum number of experiments. This is especially important for experimental optimisation with a large number of variables. In addition, this method is robust to experimental errors, i.e., it allows you to identify an almost stationary region and covers extremes, even in cases where the experimental data have some inaccuracies compared to the true values of the optimization parameters. The process of determining the most optimal ratios of antioxidants using the simplex planning method consists of the sequential implementation of several critical steps aimed at achieving the best results [12, 23]. This methodology provides a structured approach to optimizing formulations, allowing for multifactorial interactions between components and their impact on optimization parameters. It is important to consider each of the following steps to fully understand and effectively use this method:

Formation of the initial set of compositions: The initial stage involves the preparation of an initial set of formulations, each containing a specific ratio of antioxidants. This set can be carefully selected to include various possible variations and combinations of components:

1. Conducting experiments to determine the optimization parameter: In this stage, experiments are performed to measure the optimization parameter (e.g., product quality) for each of the formulations in the initial set. This allows you to obtain the value of this parameter for further analysis.
2. Selection of the optimal composition: Based on the results of the experiments, the formula that has the best performance of the optimization parameter is selected and analyzed. This can be achieved, for example, by finding the minimum or maximum value of this parameter.
3. Determination of a new composition: After selecting the optimal composition, the next simplex (points for the next experiments) is calculated using the appropriate formula based on the coordinates of the optimal composition.
4. Perform additional experiments for the new composition: A new set of experiments is performed to determine the optimization parameter for the newly selected composition.

This sequential process allows to systematic identify the optimal ratios of antioxidants that maximize the achievement of the desired product characteristics. This optimization method was used to study and optimize the composition of an antioxidant composition that included four key ingredients: mint, thyme, Biovit (a wheat germ product), butter and eggs (for the preparation of minced fish, such as European fish). The optimization was done by determining the optimal proportions of these components to achieve the most positive results. The variable factors in the optimization process were the dry matter content of each of these components, which are part of the total dry matter in the antioxidant composition. The optimization parameters that were considered were the optical density of the antioxidant in combination with phosphorus-molybdenum acid. These parameters were chosen as critical indicators reflecting the quality characteristics and effectiveness of the antioxidant composition. Using this method, it was possible to find the optimal ratios of antioxidant components that maximize the achievement of the desired parameters of optical density and phosphorus-molybdenum acid. This approach made it possible to create an effective antioxidant composition that can be used in various food products, in particular in the preparation of stuffed fish dishes, providing them with high quality and favorable properties for consumers.

Table 2. Chemical composition of combined chopped fish products, g (per 100 g of semi-finished products).

Name	D.m.	Protein	Fat	Car.	Vitamin A	β-carotene	Vitamin C	Vitamin E	Pot.	Calcium	Iron
Stuffed fish, control	48.96	12.2	33.4	3.46	0.015	1.19	0.79	7.36	155.2	90.42	0.25
"European" Stuffed fish	52.55	9.77	32.2	4.02	0.013	0.48	1.29	0.54	152.7	73.69	0.72
"Special" chops	47.10	6.5	37.3	6.9	0.379	0.25	-	1.97	82.9	53.5	0.23

Note: D.m. – Dry matter; Car. – Carbohydrates; Pot. – Potassium.
[1] Source: compiled by the authors.

Table 2 shows the chemical composition of the combined minced fish products obtained as a result of the studies. The table includes several components: dry matter (D.m.), protein, fat, carbohydrates (Car.), vitamins (A, C, E, and β-carotene), potassium (Pot.), calcium, and iron. Dry matter content is highest in the "European" Stuffed Fish and lowest in the "Special" Chops. Protein content is highest in the Stuffed Fish Control and lowest in the "Special" Chops. Fat content is highest in the "Special" Chops and lowest in the "European" Stuffed Fish. Carbohydrate content is highest in the "Special" Chops and lowest in the Stuffed Fish Control. Vitamin A content is significantly higher in the "Special" Chops compared to the other products. β-Carotene content is highest in the Stuffed Fish Control and lowest in the "Special" Chops. Vitamin C is highest in the "European" Stuffed Fish, while it is not detected in the "Special" Chops. Vitamin E content is highest in the Stuffed Fish Control and lowest in the "European" Stuffed Fish. Potassium content is highest in the Stuffed Fish Control and lowest in the "Special" Chops. Calcium content is highest in the Stuffed Fish Control and lowest in the "Special" Chops. Iron content is highest in the "European" Stuffed Fish and lowest in the "Special" Chops. The Stuffed Fish Control generally has higher protein and fat content compared to the other two products, making it a richer source of these nutrients. It also has the highest β-carotene and vitamin E content, suggesting a stronger antioxidant profile. The "European" Stuffed Fish has a slightly higher dry matter content and the highest vitamin C content, indicating it might be beneficial for boosting the immune system. It also contains the highest iron content, which is crucial for preventing anemia. The "Special" Chops have the highest fat and carbohydrate content, providing more energy but also potentially more calories. Its significantly higher vitamin A content suggests enhanced benefits for vision and immune function. The key findings of this study are highlighted in Figure 5.

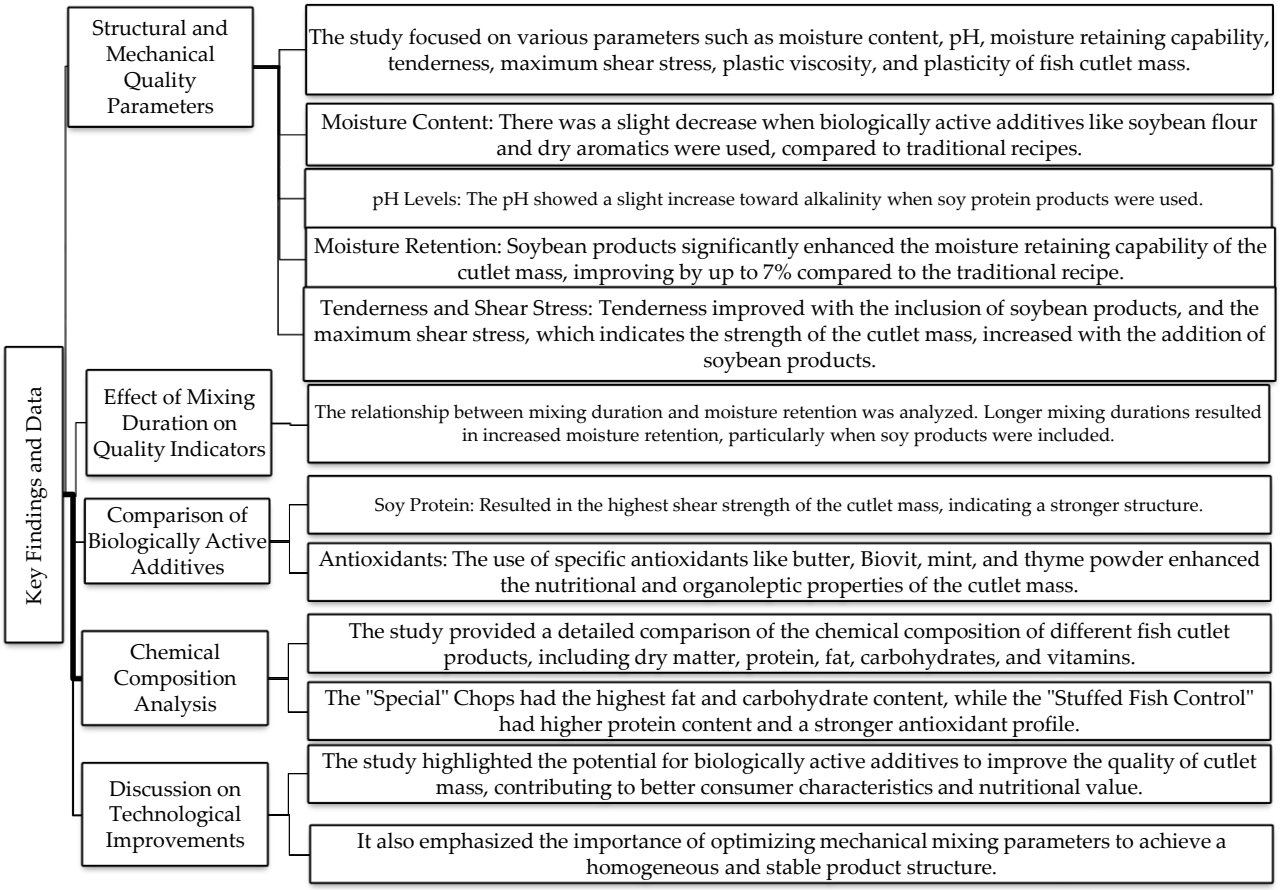

FIGURE 5. Key Findings and Data of the Study.

V. DISCUSSION

The discussion of the study results reveals important prospects for further improvement of food production technologies. The results of the study allow us to conclude that biologically active additives have a significant potential for improving the quality of cutlet mass. This important information underlines the prospects of using such additives in the food industry. The introduction of biologically active additives into product formulations contributes to a positive change in consumer characteristics, which has a direct impact on the health and nutritional value of the final product. This means that the final product has a higher nutritional value and can contribute to improving the diet of consumers. Additionally, evidence of the positive impact of dietary supplements on the quality of cutlet mass underlines their role in preserving natural nutrients. This is an important aspect, as the preservation of nutrients during food processing is key to ensuring optimal nutritional value.

The research also led to the discovery that the process of mechanical mixing has a significant impact on the structural characteristics of the cutlet mass. The use of optimal mixing modes proved to be a decisive factor in the formation of a more homogeneous and stable product structure, which in particular has a positive effect on its textural and mechanical properties. The focus on achieving optimal mechanical mixing parameters leads to improved internal equilibrium of the components, their uniformity and interaction. This, in turn, results in a product with a more stable microstructure, which can provide more consistent and predictable textural and mechanical characteristics. The addition of bioactive additives to the mixing process further enhances the positive effect. Such additives contribute to the formation of a complex structure where mechanical action and biological activity interact to create a product with the highest stability and quality. These identified links between mechanical mixing and the addition of bioactive ingredients open up new opportunities for developing products with improved performance and open the door to further innovation in food production. The data obtained also confirm the synergistic interaction of various components present in dietary supplements. This may open up new opportunities for the development of innovative technological solutions and formulations of food products with improved characteristics.

According to N.E. Marshall et al. [10], scientific information in the field of nutrition at the present stage indicates significant challenges associated with providing the human body with all the necessary macronutrients and micronutrients through normal nutrition. It has been suggested that in modern life, it is becoming increasingly difficult to achieve an adequate supply of essential nutrients through traditional nutrition. One of the most important trends in food technology is the development of innovative food products with increased nutritional value. These products aim to influence various physiological processes in the human body and have the potential to improve resistance to various diseases. To achieve this effect, it is necessary to introduce special functional ingredients with specific physiological properties into food products. This new paradigm in nutrition aims to create products that help improve people's nutrition and health by filling the need for essential nutrients and functional components. It is known that some functional ingredients, such as antioxidants, prebiotics, vitamins, and minerals, can help improve physiological functions and reduce the risk of disease.

Referring to the work of N.E. Marshall et al. [10], current findings support their claim regarding the difficulties in providing enough nutrition through standard meals. This study reveals that incorporating physiologically active ingredients into cutlet mass formulations can greatly improve nutritional quality. The use of soy products was found to boost moisture retention by 5.3-7% while increasing tenderness and structure. These findings suggest that the judicious use of chemicals can fill nutritional deficiencies in current diets, potentially leading to the production of more nutritionally complete food products.

Referring to the definition of B. Hennchen [11], the creation of new-generation food products today poses several important challenges that require an integrated approach. This is due not only to the market demand for innovative products but also to the need to update the assortment, ensure the rational use of raw materials and reduce the technological cycle of production, in particular, in the restaurant industry [24-26]. Modern advances in the field of nutritional physiology and biochemistry are key to developing new products that meet the requirements of current trends. An important task is to create products that meet different gastronomic preferences and nutritional requirements. At the same time, they should have high nutritional and biological value, considering the needs of different segments of the population. One of the most promising areas is to explore the use of affordable and cost-effective sources of protein in the diet. This may include the use of plant-based protein sources, and alternative protein sources from unused raw materials and waste, which will help improve the biological value of products and provide the population with important nutrients.

Current findings clearly confirm B. Hennchen's [11] focus on the importance of taking an integrated strategy when developing new-generation food items. This research demonstrates how combining mechanical mixing optimization with carefully chosen additives can improve product quality. For example, the study found that

adding soy flour increased the ultimate shear stress by 14%, indicating improved structure. This integrated approach indicates the possibility of developing goods that not only meet nutritional requirements but also please various gourmet preferences, thereby solving the issues identified by the scientist.

Researchers U.E. Obianwuna et al [6] found that the introduction of protein supplements and plant materials with antioxidant properties can significantly improve the product's resistance to oxidation and ensure its quality for a longer time. This is especially important in the context of nutrient retention and flavour preservation. Chopped products are a very convenient object for the introduction of protein additives and plant materials with antioxidant properties. This allows you to precisely adjust the composition and characteristics of the product, ensuring the desired level of protein and antioxidants. Organoleptic properties, such as texture, taste, and aroma, can also be improved by the introduction of plant-based raw materials. This approach not only allows for a qualitative change in food products but also helps to reduce the environmental impact and ensure a more sustainable and balanced diet for consumers.

This research confirms and expands on the conclusions of U.E. Obianwuna et al. [6] about the advantages of protein supplements and plant materials with antioxidant capabilities. According to current findings, product quality was enhanced when antioxidant-rich substances like butter (15%) and Biovit (5%) were combined with mint and thyme powder (0.003%). This suggests that precisely designed antioxidant blends can improve the nutritional content and durability of meat products, creating new opportunities for food sector product development.

S. Esteghlal et al. [7] determined that heat treatment processes can lead to the direct destruction of amino acids, which reduces their amount and biological value of the product. In addition, heat treatment can cause amino acids to interact with other components of the product, such as carbohydrates and lipids. This can lead to the formation of various chemical compounds that affect the properties of the protein. A particularly important aspect is the formation of cross-links between functional groups of individual amino acids during heat treatment. This can lead to changes in protein structure and functional properties. Such cross-links can affect the solubility of the protein, its gelling, and its interaction with other product components. Considering these influences, it is important to develop optimal heat treatment methods that would ensure the maximum number of amino acids and biological value of the protein is preserved. Additional strategies can also be used, such as the introduction of antioxidants or other components that can reduce the negative effects of heat treatment on the protein.

The findings of this manuscript on mechanical processing corroborate the work of S. Esteghlal et al. [7] on the effects of heat treatment on amino acids. While scientists focused on heat-induced alterations, this study shows that mechanical mixing factors have a major impact on protein structure and functionality. This shows that optimizing protein quality in food items requires a holistic approach that takes into account both thermal and mechanical processes.

M.J. Santos et al. [9] have shown that culinary formulations are complex ingredient combinations where proteins from different products interact to form qualitatively new structures and flavour characteristics. However, only a few ingredients in a recipe can determine the qualitative and quantitative protein composition of the finished product, while others may have a lesser impact on this aspect. Usually, only a few key ingredients in a recipe that have a high protein content and optimal amino acid composition are the main sources of protein for the finished product. Other ingredients may add flavour, texture, aroma, and other organoleptic properties, but their contribution to the protein quality may be less significant. For example, in the preparation of meat dishes, meat is the main source of protein, which determines its quality composition and texture after cooking [27-29]. Other ingredients, such as spices, oils, vegetables, etc., may add flavour and aroma but do not have a significant impact on the basic protein composition of the dish [30, 31].

Current findings further add to the observations of M.J. Santos et al. [9] on culinary compositions. While they stated that only a few ingredients influence a finished product's protein composition, this research shows that even small amounts of additives (such as 0.003% mint or thyme powder) can have a considerable impact on overall product quality. This suggests that careful study of even minor elements is critical in product formulation.

As noted by E. Herz et al. [8], an increase in the degree of minced meat grinding leads to an improvement in its structure, as well as an increase in viscosity, stickiness, and viscosity properties. This can help improve the texture and consistency of finished products, providing a more uniform and softer structure. In addition, appropriate mincing of the minced meat can have a positive effect on the viscosity and stickiness of the product, which can affect its ability to form and retain during cooking.

These results confirm and expand upon the conclusions made by E. Herz et al. [8] on the connection between product structure and mincing degree. This investigation offers precise information on the effects of various mixing settings on stickiness, viscosity, and structural integrity. For instance, it was discovered that the

best mixing circumstances produced a plastic viscosity range of 17–20 Pa/s, which enhanced the consistency and texture.

Thus, the rheological characteristics of minced meat are closely related to its grinding and processing, and they determine the final quality aspects of the finished products. Optimising these parameters can lead to high-quality and tasty food products.

VI. CONCLUSION

The research results show a significant dependence of the structural and mechanical quality indicators of cutlet mass on several factors, in particular, the peculiarities of the process of mechanical mixing of the product and the use of biologically active additives. The identified relationships indicate complex interrelationships between these parameters and their impact on the quality of the final product. The optimal characteristics of the cutlet mass are reflected in the following: moisture content ranges from 45-52%, tenderness are in the range of 470 to 530 cm2/g of total nitrogen, maximum shear strength varies between 250-280 Pa, and plastic viscosity covers values from 17 to 20 Pa/s. This approach is essential for further improving technological processes and creating high-quality food products that meet modern consumer requirements. This interaction demonstrates the presence of a synergistic effect between the various components that make up the antioxidants under study. The result of this study was the creation of a new formulation, which successfully combines components with antioxidant properties and complementary fillers: butter (15%), Biovit (5%) and a small amount of mint (thyme) powder in the amount of 0.003%. This study shows that the interaction of the components is manifested at the level of stationary points, which, according to the data obtained, confirms the presence of a reinforcing effect in the reactions between the substances. The new formulation paves the way for improving food products, ensuring their quality and more balanced composition. This step is important in the development of the food industry and reflects the desire to ensure high-quality products and meet the needs of modern consumers.

Summarizing the results of the study, it can be stated that the introduction of a new formulation with antioxidants improves the quality and nutritional properties of cutlet mass, in line with modern consumer requirements. This study opens up new prospects for optimizing the technological processes of cooking cutlet mass using antioxidants, which in turn can improve the quality and nutritional properties of the product.

This study has made several key contributions to the field of food science and technology. It has provided a detailed understanding of how mechanical mixing parameters and biologically active additives can be optimized to enhance the structural and mechanical properties of cutlet mass. The findings offer practical recommendations for the food industry, which can be directly applied to improve the quality and nutritional value of cutlet mass and similar food products. Moreover, this research has expanded the scientific knowledge regarding the interactions between mechanical processes and biologically active additives, contributing to the development of innovative food products that align with modern consumer preferences.

Funding statement

This research received no external funding.

Author contribution

All authors made an equal contribution to the development and planning of the study. All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

Data are available from the authors upon request.

Acknowledgments

The authors would like to acknowledge the assistance of the Editor and Reviewers in the preparation of the article for publication.

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