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# APPLICATION OF ENZYME TREATED COLLAGEN CONTAINING RAW MATERIALS IN FORMULATIONS OF POULTRY MEAT PRODUCTS

***Nataliia Patsera***, *Deputy Head of Department of Informational Support, Standardization and Metrology*
*https://orcid.org/0000-0001-8737-9997*
***Liubov Voitsekhivska***, *PhD, Engineering, Head of Department of Technology of Meat Products*
*https://orcid.org/0000-0001-7595-1845*
***Sergii Verbytskyi***, *PhD, Engineering, Head of Department of Informational Support, Standardization and Metrology*
*https://orcid.org/0000-0002-4211-3789*
***Yurii Okhrimenko***, *Main Specialist Department of Technology of Meat Products*
*https://orcid.org/0000-0002-5910-1370*
***Volodymyr Bosak***, *PhD, Engineering, Senior Researcher of Department Analytical Research and Food Products Quality*
*https://orcid.org/0009-0005-8701-0133*
Institute of Food Resources of NAAS, Kyiv, Ukraine

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***Subject.*** *Meat processing industry of Ukraine is facing a severe shortage of animal-based raw materials and a significant deterioration in their quality. Biotechnological methods for enzymatic processing of meat raw materials offer a promising solution. Scientific substantiation of the possibility and feasibility of using fermented collagen-containing raw materials in the production of meat products, in particular, cooked sausages as a high-quality substitute for valuable meat raw materials.* ***Methods.*** *In experimental samples of cooked sausage with different contents of fermented meat raw materials from the feet of broiler chickens, the mass fraction of fat, protein and moisture, pH and water activity were determined according to standard methods, and the rheological index was determined using a universal mechanical testing machine.* ***Results.*** *A significant effect of fermented raw material from broiler chicken feet on the formation of the quality, structural and mechanical characteristics and technological efficiency of the finished product was revealed. An increase in the water-holding capacity was recorded, caused by the formation of a spatial protein-collagen matrix that effectively retains both free and bound water, from 80.3% in the control sample to 86.3% and 91.4% in the fermented sausage samples. The sausage yield increased from 95.0% in the control sample to 97.1% and 98.4% in the fermented sausages. The obtained results indicate that the use of fermented raw material from broiler chicken feet in the technology of cooked sausages is scientifically and technologically substantiated. The most balanced in terms of the set of indicators is a sample from 10% fermented raw material, and a sample from 20% of such raw material is characterized by the maximum technological advantages.* ***Scope of results.*** *The results can be used by food manufacturers to develop technologies for producing cooked sausages using fermented collagen-containing poultry raw materials as a high-quality substitute for valuable meat raw materials. Such technological solutions contribute to the innovative development of the meat industry through the integrated use of raw materials and resource conservation.*

***Key words****: meat industry, meat raw materials, collagen-containing raw materials from poultry, enzyme processing, boiled sausages, resource saving*

# ВИКОРИСТАННЯ ОБРОБЛЕНОЇ ФЕРМЕНТАМИ КОЛАГЕНВМІСНОЇ СИРОВИНИ У СКЛАДІ ПРОДУКТІВ ІЗ М'ЯСА ПТИЦІ

***Пацера Н. М.***, *заст. завідувача відділу інформаційного забезпечення, стандартизації та метрології*
*https://orcid.org/0000-0001-8737-9997*
***Войцехівська Л. І.,*** *к.т.н., завідувачка відділу технології м'ясних продуктів*
*https://orcid.org/0000-0001-7595-1845*
***Охріменко Ю. І.***, *головний фахівець відділу технології м'ясних продуктів*
*https://orcid.org/0000-0002-5910-1370*

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***Вербицький С. Б.**, к.т.н., завідувач відділу інформаційного забезпечення, стандартизації та метрології*
*https://orcid.org/0000-0002-4211-3789*
***Босак В. З.**, к.т.н., с.н.с. відділу аналітичних досліджень та якості харчової продукції*
*https://orcid.org/0009-0005-8701-0133*
Інститут продовольчих ресурсів НААН, Київ, Україна

***Мета.** М'ясопереробна промисловість України наразі стикається з гострим дефіцитом сировини тваринного походження та суттєвим погіршенням її якості. Перспективним у цьому напрямку є використання біотехнологічних способів ферментативної обробки м'ясної сировини. Наукове обґрунтування можливості та доцільності залучення ферментованої колагенвмісної сировини у виробництво м'ясних продуктів, зокрема, варених ковбас, як якісного замінника цінної м'ясної сировини. **Методи**. У дослідних зразках вареної ковбаси з різним вмістом ферментованої м'ясної сировини з лап курчат-бройлерів визначали масову частку жиру, білка та вологи, pH та активність води згідно зі стандартними методами, реологічні показник – на універсальній механічній тест-машині. **Результати.** Виявлено суттєвий вплив ферментованої сировини з лап курчат-бройлерів на формування якості, структурно-механічних характеристик та технологічної ефективності готової продукції. Зафіксовано підвищення вологоутримувальної здатності, зумовлене формуванням просторової білково-колагенової матриці, яка ефективно утримує як вільну, так і зв'язану воду, від 80,3% у контрольному зразку до 86,3% та 91,4% у зразках ферментованих ковбас. Вихід ковбас зріс з 95,0% у контрольному зразку; до 97,1% та 98,4% у ферментованих ковбасах. Отримані результатів свідчить, що використання ферментованої сировини з лап курчат-бройлерів у технології варених ковбас є науково та технологічно обґрунтованим. Найбільш збалансованим за сукупністю показників є зразок із 10% ферментованої сировини, натомість зразок із 20% такої сировини характеризується максимальними технологічними перевагами. **Сфера застосування результатів.** Результати можуть бути використані виробниками харчових продуктів для створення технологій виробництва варених ковбас із використанням ферментованої колагенвмісної сировини з птиці як якісного замінника цінної м'ясної сировини. Такі технологічні рішення сприяють інноваційному розвитку м'ясної промисловості на основі комплексного використання сировини та ресурсозбереження.*

***Ключові слова:** м'ясна промисловість, м'ясна сировина, колагенвмісна сировина з птиці, ферментне оброблення, варені ковбаси, ресурсозбереження*

**Problem statement.** The meat processing industry of Ukraine is facing an acute shortage of raw materials of animal origin and a significant deterioration in their quality. According to [1], up to 14% of protein resources in the meat industry of Ukraine are not properly utilized. The modern meat processing industry is actively seeking ways to improve the economic efficiency of production, maintain quality and ensure the sustainability of technologies. The growing need to provide production with meat resources leads to the necessity of involving raw materials with a high content of connective tissue in technological processes and searching for ways to improve its technological properties [2]. The use of biotechnological methods of enzymatic treatment of meat raw materials is promising in this direction. The advantages of using proteolytic enzyme preparations are due to high catalytic activity, the possibility of implementation without the use of extreme temperatures and aggressive environments, the specificity of enzyme action and the ease of inactivation at traditional heat treatment temperatures of meat products [3]. These methods of technological processing impart physicochemical and organoleptic properties to meat raw materials suitable for the manufacture of functional meat products intended for the formation of menus for both children [4] and the elderly [5].

In this context, the use of fermented collagen-containing raw materials from non-traditional sources, particularly raw materials from poultry processing, offers good prospects. This is supported by the fact that collagen plays a key role in the structure of meat products, providing water-holding capacity, elasticity, and system stability. Fermentation enhances the functional properties of this raw material, improving its digestibility, sensorial characteristics, and technological adaptability. Collagen from chicken feet is characterized by a high content of α-chains and good gelling properties [8]. The addition of collagen hydrolysate in the recipe for cooked sausages in an amount of 5 to 15%

improves consistency, increases product yield, and enhances the stability of the minced meat during heat treatment. Fermented collagen peptides are able to interact with myofibrillar proteins of meat, forming a strengthened protein matrix, which positively affects the structural and mechanical properties of the finished product. Collagen can be used to partially replace fat, which is important in the production of reduced-calorie products. It should be noted that fermented collagen raw materials, with appropriate heat treatment, fully meet the requirements of microbiological safety [9–11].

The production technology for fermented collagen-containing raw materials from chicken feet involves several key steps: washing and sanitary preparation of the raw materials, grinding, thermal degreasing, isolation of collagen-containing fractions, enzymatic treatment, and drying or stabilization. Fermentation is a key step, as enzymes break down complex protein structures into fragments capable of forming a gel or acting as water-retaining agents [6, 7]. Control of pH is a critical parameter determining enzyme activity and collagen stability.

In cooked sausage production, fermented raw materials are typically added during the cutting stage, along with water or ice. In many recipes, their proportion ranges from 3-10%, and sometimes up to 20% in economy-class production. Fermented collagen additives promote the formation of a dense, uniform minced meat structure, reduce the risk of bouillon-fat swelling, and improve moisture binding. Technological studies show that such raw materials can partially replace beef, pork or mechanically separated meat without significantly affecting the sensorial properties.

The development of a technology for producing collagen concentrate from broiler chicken feet, one of the most common waste products in the poultry processing industry, is described in [12, 13]. Feet contain up to 25% collagen, making them a valuable raw material for the food industry. The work describes the stages of purification, demineralization, and hydrolysis of tissues, allowing for the production of a concentrate with a high proportion of soluble collagen. Enzymatic methods are preferable over acidic ones due to the lesser destruction of protein structures. The resulting product after enzymatic processing has more favorable rheological properties than concentrate obtained by chemical methods. The collagen concentrate hydrates well and has a high water-holding capacity (WHC). This allows it to be used as a functional additive in meat products to increase the yield of finished products, and the absence of keratin and mineral impurities positively affects the gel-forming properties of the concentrate. The optimal temperature for enzymatic hydrolysis is 50–55°C; it is rational to use a combined technological scheme “demineralization → fermentation → drying”.

In [14], methods for extracting soluble collagen from broiler chicken feet were studied and the main properties of the obtained product were determined. The authors emphasize that feet are a convenient source of pure type 1 collagen. The study compared acid extraction, enzymatic hydrolysis, and combined methods. A high yield of soluble collagen was ensured by enzymatic treatment with proteases. The obtained collagen had a high degree of purity. Spectroscopic studies showed the preservation of the triplet structure of tropocolagen. Optimum hydrolysis conditions were: temperature of 45–50°C, pH 6.5–7.0, and duration of 3–6 hours. The authors [15], evaluating the effect of hydrolyzed collagen and gelatin from chicken feet on the quality of boiled chicken sausages with reduced fat content, found that the introduction of collagen increased the elasticity and cohesiveness of the minced meat, and the hydrolysate contributed to the formation of a stable protein matrix. Sausages with the addition of 1-3% collagen exhibited significantly lower weight loss during cooking, while paw gelatin provided improved gelling properties in the finished product. The minced meat structure became more uniform, and color indices remained stable, demonstrating the compatibility of collagen with the protein system of meat. The collagen supplement also increased the water-holding capacity (WHC). The authors [15] consider 1.5–2% collagen to be the optimal amount in the formulation. According to [16], complex processing based on collagen hydrolysis is advisable, with the possibility of obtaining gelatin, peptides, and hydrolysates. It has been shown that the degree of hydrolysis has a significant impact on the functionality of collagen peptides. Collagen peptides increase WHC and the stability of emulsions. The gelatin from feet is distinguished by its high gelling properties, and peptides contribute to the formation of an elastic texture of sausage mince.

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Collagen from feet can also serve as a source of bioactive components. The work concludes that feet are a promising, undervalued raw material. Similar conclusions were drawn by the authors [17] regarding the effect of adding a fermented extract of collagen from broiler chicken feet on the quality of beef meatballs. The degree of hydrolysis after fermentation with Lactobacillus plantarum was studied. It was found that the fermented raw material has high solubility. The authors point out that it enhances the gel properties of the minced meat. Due to fermentation, collagen acquires acidity, which increases the WHC of the minced meat. Meatballs with the fermented additive had better elasticity. The authors believe that collagen contains water in the protein matrix, and collagen peptides are capable of improving fat emulsification. The study demonstrates the high potential of fermented raw materials for the meat industry. In [18], a process for obtaining collagen hydrolysate from low-value raw materials in the poultry processing industry is described. It was found that enzymatic hydrolysis of proteases allows obtaining low-molecular fractions. The morphology of hydrolyzed collagen is described. The hydrolysate is highly stable, and the peptides do not form a gel, but they bind water well. Therefore, the hydrolysate can be used in meat systems to increase juiciness and enhance the stability of emulsions. The authors [19] analyze the effect of heating and hydration on the structure of collagen fibers. It was shown that heating causes denaturation and conversion to gelatin, while fermentation increases the ability of the fibers to retain water. The researchers used morphological analysis. It was found that the collagen structure becomes looser. This simplifies further technological processing and increases the solubility of the protein. This is important for the meat industry, as it facilitates mixing with ground meat. The work also describes optimal processing conditions. The authors demonstrate that proper preparation of feet ensures maximum collagen yield. Preliminary fermentation is shown to promote uniform swelling of the fibers. Structural configurations allow for the production of stable solutions. The study emphasizes the importance of pre-softening the collagen in the feet. This allows them to be used as an alternative to gelatin in food systems.

An analysis of literary sources makes it possible to state that fermented broiler chicken feet are a promising, inexpensive raw material for producing edible collagen with high functional properties and have high potential as a secondary poultry raw material as a substitute for some meat in finished products, particularly cooked sausages [2]. In general, information on the use of collagen-containing raw materials obtained during industrial processing of slaughtered poultry for the production of meat products is available in numerous sources, such as [23–25].

**Research objective.** Scientific substantiation of the feasibility and feasibility of using fermented collagen-containing raw materials in the production of meat products, particularly cooked sausages, as a high-quality substitute for valuable meat raw materials.

**Materials and methods.** The following were the objects of the study:

1) Laboratory-fermented raw meat from broiler chicken feet, separated from bones, using the enzyme preparation Protease C (manufactured by the Ladyzhyn Plant of Bio- and Enzyme Preparations "Enzym");

2) Experimental samples of cooked sausage with varying contents of fermented raw meat from broiler chicken feet, produced in the Department of Technology of Meat Products from raw materials obtained from retail outlets.

The following parameters were determined during the study:

- Hydroxyproline content – according to DSTU ISO 3496:2014 "Meat and meat products. Determination of hydroxyproline content (ISO 3496:1994, IDT);
- Fat content – according to DSTU 8380:2015 "Meat and meat products. Method of measurement of mass fraction of fat" and DSTU ISO 1443:2005 "Meat and Meat Products. Determination of total fat content" (ISO 1443:1973, IDT);
- Protein content – according to DSTU ISO 937 2005 "Meat and Meat Products. Determination of nitrogen content (reference method)" (ISO 937:1978, IDT);

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- Water content – according to DSTU ISO 1442:2005 "Meat and meat products. Method for determination of moisture content (reference method)" (ISO 1442:1997, IDT);

- pH – according to DSTU ISO 2917-2001 "Meat and meat products. Measurement of pH (reference method)" (ISO 2917:1999, IDT);

- Water activity ($a_w$) – according to DSTU ISO 21807:2007 "Microbiology of food and animal feeding stuffs. Determination of water activity";

- Rheological parameters – according to the guidelines "Determination of the Structural and Mechanical Properties of Meat Products" and the operating instructions for the SANS universal mechanical testing machine, SMT 2000 series, model 2503.

Statistical processing of the obtained results was performed based on the calculation of arithmetic means and standard deviations. All experimental data are the results of 3-5 parallel determinations.

**Presentation of the main research results.** To conduct the research, pilot samples of cooked sausages were prepared under laboratory conditions. The recipe for these samples was developed taking into account literature sources and the results of preliminary work on the fermentation of collagen-containing raw materials from broiler chicken feet. The following factors were principal in determining the composition of the pilot samples:

– Enzymatic treatment with proteases ensures the highest yield of soluble collagen with a high degree of purity;

– Data from preliminary studies of fermented raw materials from broiler chicken feet allow this raw material to be used as a partial substitute for traditionally used protein in sausage mince.

The following pilot samples were prepared for the research:

– Sample 1, fermented raw material content 10%;

– Sample 2, fermented raw material content 20%;

– Control sample, without fermented raw materials.

The recipe composition of the pilot samples is presented in Table 1.

*Table 1*

**Formulations of samples in%**

| Components | Control | Sample 1 | Sample 2 |
|---|---|---|---|
| | Composition,% | | |
| Poultry meat | 50.0 | 50.0 | 50.0 |
| Pork | 50.0 | 35.0 | 25.0 |
| Fermented raw materials | 0.0 | 10.0 | 20.0 |
| Salt | 2.5 | 2.5 | 2.5 |
| Sugar | 0.1 | 0.1 | 0.1 |
| Pepper, spices (mix) | 0.05 | 0.05 | 0.05 |

The control sample was prepared using a traditional recipe without the addition of fermented raw materials. The experimental samples included partial replacement of meat raw materials with fermented raw materials from broiler chicken feet at a rate of 10% (sample 1) and 20% (sample 2). This approach allowed us to establish patterns in the changes in physical, chemical and technological parameters depending on the amount of the raw materials used in the formulation. The minced meat for samples 1 and 2 was prepared using broth obtained by boiling broiler chicken feet before fermentation.

Fermented collagen-containing raw materials contain not only collagen, but also elastin, reticulin, mucins, mucoids, and other substances. However, collagen, including its soluble component, is of primary importance. The collagen content of fermented broiler chicken feet ials, ranging from 8.8% to 9.6%, was determined experimentally based on the content of the amino acid hydroxyproline. This is a relatively high value; the calculated total protein fraction in the fermented

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broiler chicken feet is approximately 58.2% of the total protein content. Thus, mathematical modeling was used to predict the expected amount (15%) of the total protein sample, taking into account the protein percentages of all minced meat components in the test samples.

The results of studies of the key physical, chemical, functional and technological parameters of the test samples of cooked sausage containing fermented broiler chicken paw raw materials are presented in Table 2.

*Table 2*

**Physical, chemical, functional and technological parameters of experimental samples of boiled sausages with the addition of fermented raw materials from broiler feet**

| Parameter | Control | Sample 1 (10%)* | Sample 2 (20%)* |
|---|---|---|---|
| Water (%) | 75.03 | 74.86 | 74.92 |
| Protein (%) | 15.35 | 16.03 | 15.91 |
| Fat (%) | 8.05 | 7.13 | 7.14 |
| Bound water content,% of total water,% | 80.34 | 86.26 | 91.44 |
| Bound water content,% of meat | 61.21 | 63.18 | 65.47 |
| Share stress, kPa | 22.55 | 10.73 | 9.55 |
| Product yield (%) | 95.0 | 97.1 | 98.4 |

* Amount of added fermented broiler chicken feet,%

Water content analysis showed that the water content in the control and test samples was within a narrow range of 74.86-75.03%, indicating no negative impact of the fermented material on the product's water balance. This water content stability is explained by the ability of collagen proteins in the fermented state to form a spatial structure that retains water in a bound state.

The protein content in the test samples exceeded that of the control sample. Specifically, in sample 1 (10% fermented material – FM), the protein content increased to 16.03%, which is 0.68% higher than the control. In sample 2 (20% FM), the protein content increased to 15.91%, compared to 15.35% in the control sample. The increase in this indicator is due to the introduction of collagen proteins and low-molecular-weight peptides as a result of raw material fermentation.

The fat content in the experimental samples of cooked sausages made of FM decreased compared to the control, reaching 7.13–7.14% versus 8.05%. The reduction in fat content is a positive factor, as it contributes to the formation of products with reduced energy value and improved dietary properties.

The pH in the test samples increased to 6.54–6.57 compared to 6.42 in the control sample. This is explained by the alkalinity of the enzyme preparation, protease C (alkaline fungal protease). A shift in the pH toward slightly alkaline pH promotes increased protein hydration capacity, which has a positive effect on the structure formation and stability of the minced meat system.

One of the most indicative process parameters is the moisture-binding capacity. In the control sample, it was 80.3%, while in the samples with 10% and 20% FM, it increased to 86.3% and 91.4%, respectively. This increase is a consequence of the formation of a spatial protein-collagen matrix, which effectively retains a significant amount of moisture (both free and bound) during heat treatment.

Increasing the WHC directly impacted the yield of the finished product. The yield of cooked sausages increased from 95.0% in the control sample to 97.1% in the sample with 10% FS and 98.4% in the sample with 20% FM. These results have important practical implications for the meat processing industry, as they help reduce process losses in sausage production.

The rheological properties of boiled sausages varied significantly depending on the FS content. The shear force in the control sample was 22.6 kPa, while in the test samples, this value decreased to

10.7 and 9.6 kPa, respectively. This reduction in shear force indicates improved tenderness, elasticity, and juiciness of the product.

**Conclusion.** The research results confirmed the feasibility of using fermented raw materials from broiler chicken feet in the technology of cooked sausages. Its significant influence on the physical, chemical, rheological and technological parameters of the finished product was established. The use of such raw materials contributes to the rational processing of secondary resources of poultry processing, increased production efficiency and expansion of the range of meat products. The obtained results form the basis for the development of technology and regulatory documentation for the production of cooked sausages. An increase in the WHC was recorded, caused by the formation of a spatial protein-collagen matrix that effectively retains both free and bound water, from 80.3% in the control sample to 86.3% in sample 1 (10% FM) and 91.4% in sample 2 (20% FM). This increase had a direct impact on the yield of the finished product. The yield of cooked sausages increased from 95.0% in the control sample up to 97.1% in sample 1 and 98.4% in sample 2.

Thus, the obtained research results and their analyses demonstrate that the use of fermented raw material from broiler feet in cooked sausage production is scientifically and technologically sound. The sample containing 10% fermented raw material demonstrated the most balanced overall performance, while the sample containing 20% fermented raw material demonstrated the greatest technological advantages.

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