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Edible collagen coatings from chicken skin for longer shelf life of meat and dairy food systems

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Abstract:
Collagen is a popular component of edible coatings that protect food products during storage. This article introduces a new antioxidant and antibacterial edible coating made from broiler chicken skin as a source of collagen. The coating was tested on meat and dairy products with high moisture and fat content, namely sausage, jellied beef, and soft cheese.
A set of standard research methods made it possible to determine the physicochemical, sensory, and microbiological properties of broiler chicken skin and the experimental edible coating, as well as to compare the coated and uncoated meat and dairy products. A digital micrometer and a DVT Devotrans GPUG model revealed the structural and mechanical properties of the test products. The protein fraction was described using a method based on the extraction of sarcoplasmic proteins from muscle tissue in a low-ionic-strength buffer solution to produce fractions of water-soluble, salt-soluble, and alkali-soluble proteins. The water activity coefficient was obtained using an Aqualab 4TE analyzer with a dielectric humidity sensor.
Alcalase (Novozymes, Danmark) was chosen as the optimal enzymic preparation available on the Russian market for the hydrolysis of collagen-containing raw materials. Its optimal concentration was 0.3% of the raw material weight after preliminary swelling in water. The optimal hydrolysis conditions were as follows: heating medium temperature – 52°C, exposure time – 5 h. The research resulted in a production algorithm and a formulation modeled in the MultiMit automated expert system.
The new technology for edible coating from chicken skin collagen can be used in the meat and dairy industries to extend the shelf-life of final products due to antibacterial and antioxidant effects.

Keywords: Collagen-containing raw material, chicken skin, enzyme, hydrolysis, alcalase, edible coating, formulation, meat and dairy products

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INTRODUCTION

Edible collagen coatings can be fortified with natural plant-based ingredients, such as essential oils and oleoresins. They give collagen useful antimicrobial and antioxidant properties. These innovative coatings and castings extend the shelf life of many foods [1], particularly high-moisture cheeses or meat products, which are perishable in cold storage [2].

Nutraceutical and cosmetic sciences are on the lookout for new methods of extracting collagen from various raw materials [3]. So far, acidic and enzymatic hydrolyses remain the primary methods for isolating collagen from the wastes of cattle and poultry farming.

Acid hydrolysis is more popular in Europe. This method relies mainly on hydrochloric acid [4] although acetic and formic acids are also good for collagen extraction. During the procedure, raw materials are crushed, treated with an alkaline solution, and washed to obtain acid-soluble collagen. Acid hydrolysis yields mostly low-molecular-weight peptides with weak functional and biological properties (Patent no. RU 2665589 C2).

Enzymatic hydrolysis is an alternative method for collagen extraction. It relies on pepsin, trypsin, and papain. Collagen-containing raw materials are treated with pepsin, which is capable of cleaving telopeptide regions. This method is more effective than acid hydro-

lysis. To double the collagen yield, raw materials are pretreated with acid and enzyme [5].

The parameters of collagen hydrolysis include the acid type, temperature, enzyme consumption, exposure time, etc. They significantly affect the length of the polypeptide chains and, consequently, their functional and biological properties. Collagen isolated by enzymatic hydrolysis contains more low-molecular-weight peptides, and their content increases together with the enzyme concentration. Enzymatically hydrolyzed peptides possess a better functional and biological profile than those obtained by acid hydrolyzation [6]. Yet, each stage of enzymatic hydrolysis has its own detrimental factors e. g., wrong exposure time, temperature, enzyme concentration, etc. All these process violations may result in too hard or too viscous collagen coatings [7].

Some experimental methods of collagen hydrolysis involve pepsin, papain, and bovine pancreas protease [8]. The optimal hydrolysis degree was reported to belong to the samples with 10% of pepsin, 20% papain, and 28% protease. An electrophoretic analysis revealed peptides with 2 kDa of molecular weight [9].

Hydrolysates and peptides obtained by enzymatic protein hydrolysis are known to exhibit various biological activities, of which antioxidant activity is the best described one. Antioxidant peptides have low molecular weight. Despite being cheap, they are useful, safe, antimicrobial, and easily absorbed [10]. Some studies promote antioxidant peptides from fish waste because they have no restrictions in the pharmaceutical and food industries; their hydrolysis is affordable and fast [11].

The application methods also impact the effectiveness of edible coatings. Dipping or spraying technologies provide the best results. Dipping is preferable as it guarantees even and thick coating [12] that protects food from air and microorganisms.

The current search for new sources of collagen raw materials is connected with the decline in the number of slaughter cattle, the high risks of bovine spongiform encephalopathy, and some religious restrictions. In addition, natural and targeted enzymes are expensive [13, 14]. New collagen sources and functional hydrolyzed products are needed in biomedicine, biomaterials, tissue engineering, and the food industry.

Given the growing segment of semi-finished skinned poultry foods, chicken skin can be regarded as an additional and inexpensive raw material for enzymatic collagen hydrolysate and collagen-based coatings.

This study offers a new edible antioxidant and antibacterial coating from broiler chicken skin for cold storage of meat and dairy products.

STUDY OBJECTS AND METHODS

The experiments were conducted at the Russian State Agrarian University – Moscow Timiryazev Agricultural Academy, and the V.M. Gorbatov Federal Research Center for Food Systems of RAS (Moscow, Russia).

The research featured the following materials:
– chilled collagen-containing broiler chicken skin, obtained after cutting broiler carcasses into semi-finished products (sold wholesale in 1 kg packages);
– garlic, coriander, and rosemary essential oils (India);
– ginger oleoresin (India); as well as
– sausages, jellied beef, and soft cheese (Russia, purchased from retailers in Moscow).

The physicochemical parameters of collagen in the broiler chicken skin, edible coating, coated meat, and dairy products were described based on the contents of protein (State Standard GOST 25011-2017), moisture (State Standard GOST 9793-2016), fat (State Standard GOST 23042-2015), hydroxyproline, and collagen (State Standard GOST 33692-2015). The fractional analysis of proteins relied on the extraction of sarcoplasmic proteins from muscle tissue with a low ionic strength buffer solution. The fractions of water-soluble, salt-soluble, and alkali-soluble proteins were then compared to State Standard GOST 25011-2017. Water activity was measured using an Aqualab 4TE analyzer with a dielectric humidity sensor. Other parameters included hydrogen ion concentration (pH) (State Standard GOST 51478-99), amino-ammonia nitrogen (GOST R 55479-2013), and antioxidant activity (GOST 34815-2021). The antimicrobial activity was studied using microbiological express tests on dip slides and the agar diffusion method. As for the structural and mechanical properties, the thickness of the experimental coating was measured with a micrometer (0.001 mm accuracy, Fig. 1b), and the tensile strength test involved a DVT Devotrans GPUG measure model (Fig. 1a)

The sensory assessment of collagen coatings relied on State Standard GOST 33692-2015; the sensory assessment of collagen-coated products was calibrated using State Standard GOST 9959-2015 for meat and State Standard GOST 33609-2015 for cheese. The microbiological tests involved the data specified in State Standard GOST 32901-2014.

RESULTS AND DISCUSSION

Table 1 describes the quality of broiler chicken skin used as raw material.

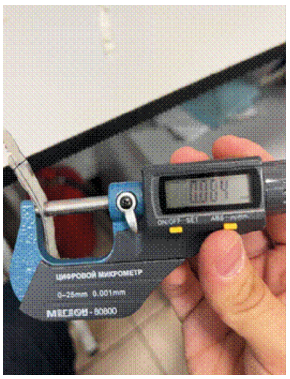
In the broiler chicken skin under study, collagen protein accounted for 31.70%. The fractional composition was dominated by alkali-soluble fraction, which was 1.9 times as big as the salt-soluble fraction. The water activity was 0.95, i. e., collagen hydrolysate had to be given additional antimicrobial properties. The fat content was quite high (Table 1), so degreasing had to be included into the production process (Fig. 2).

Amino-ammonia nitrogen develops as a result of protein breakdown by enzymes [3]. Its accumulation is a crucial indicator that highlights the hydrolysis degree.

According Table 2, the chicken skin samples hydrolyzed with alcalase had the highest amino-ammonium nitrogen content compared to the samples hydrolyzed with the other enzymes used in the experiment.

Table 3 illustrates the effect of hydrolysis time on amino-ammonia nitrogen in broiler chicken skin treated with various enzymatic preparations.

a



b

Figure 1 Measure systems for structural and mechanical properties of food coating: (a) DVT Devotrans, GPUG model; (b) digital micrometer

Table 1 Physicochemical profile of chilled broiler chicken skin

Indicators	Values
Protein mass fraction, %:	18.50 ± 1.48
Moisture mass fraction, %:	41.30 ± 3.00
Fat mass fraction, %:	37.91 ± 3.03
Oxyproline/collagen, % total proteins	37.91 ± 3.03/31.70
Fractional composition of protein (collagen), % total proteins	
water-soluble	3.90 ± 0.05
salt-soluble	5.45 ± 0.05
alkali-soluble	10.39 ± 0.10
Amino-ammonia nitrogen, mg/100 g	30.00 ± 3.00
Water activity (a_w)	0.95

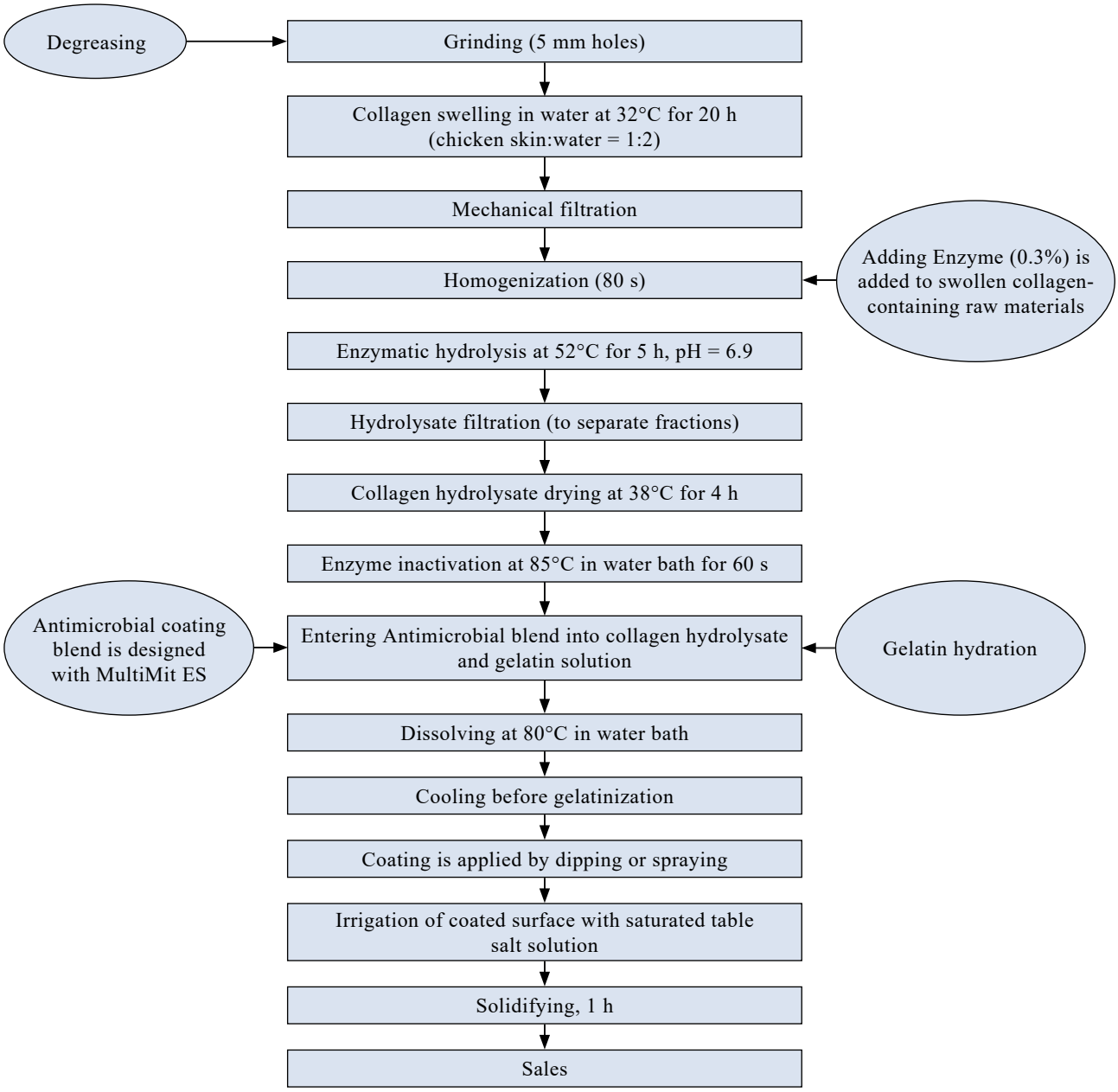


Figure 2 Scheme for obtaining edible collagen coating from broiler chicken skin by enzymatic hydrolysis

Table 2 Hydrolysis degree of broiler chicken skin obtained by various enzymatic preparations

Enzymatic preparation	Amino-ammonia nitrogen, mg/100g
Alcalase	60.0 ± 4.8
Alcalase and neutrase mix (60:40)	45.0 ± 3.6
Neutrase	32.0 ± 3.2

Table 3 Effect of enzymatic hydrolysis time on amino-ammonia nitrogen

Enzymatic preparation	Amino-ammonia nitrogen, mg/100g			
	3 h	5 h	8 h	12 h
Alcalase	48.1 ± 3.8	60.2 ± 4.8	60.0 ± 4.9	60.0 ± 4.2
Alcalase and neutrase mix (60:40)	36.0 ± 3.2	45.0 ± 3.6	46.0 ± 3.6	46.0 ± 3.6
Neutrase	25.5 ± 3.4	32.0 ± 3.2	35.0 ± 1.6	35.0 ± 3.8

Table 4 Sensory profile of collagen hydrolysate

Indicator	Description
Appearance	Uniform, spreadable, without visible collagen fiber inclusions
Color	Cream white
Smell	Typical of chicken skin, free of foreign smells

The optimal hydrolysis time for alcalase treatments was 5 h. When it lasted 8–12 h, the amino-ammonia nitrogen remained the same.

On the Russian market (October 2025), 1 kg of the enzymatic preparations cost 42,447 rubles (alcalase), 207,000 rubles (collagenase), and 89,385 rubles (neutrase). Since alcalase proved both technologically superior and economically feasible, the further research focused on this enzymic preparation. The enzymatic hydrolysis time was 5 h. The hydrolysis temperature was 520°C, as recommended by the manufacturer (Novozymes, Denmark).

Alcalase exhibited higher efficiency and specificity, allowing for better results at a lower cost. This combination of availability and high performance made alcalase preferable to other enzymic preparations for this research.

Figure 2 describes the scheme of enzymatic hydrolysis for broiler chicken skin and coating production. Table 4 summarizes the sensory profile of the collagen hydrolysate obtained according to the scheme in Fig. 2.

Table 5 contains the physicochemical properties of collagen hydrolysate obtained by inactivating alcalase in water bath at 85°C for 60 s. The parameters complied with the Interstate Standard for Animal Connective Tissue Proteins (GOST 33692).

The coating thickness ranged from 0.1 to 0.15 μm. The tensile strength in a dried sample was 17.0 ± 3.5 MPa.

A special composition was designed to be included in the edible coating. It consisted of flavor compounds that prevented microbial and oxidative spoilage. The

Table 5 Physicochemical properties of collagen hydrolysate

Indicator	Value
Moisture mass fraction, %	76.00
Fat mass fraction, %	12.00
Protein mass fraction, %	11.01
Total ash mass fraction, %	0.09
Water ions, pH	6.70
Amino-ammonia nitrogen mass fraction (mg/100g)	65.00
Collagen, % protein mass fraction	7.10
Density, g/cm^3	0.51 ± 0.20

Table 6 Antimicrobial and antioxidant edible collagen coating

Component	Mass fraction, %
Garlic (sausage, jellied beef)/coriander essential oil (cheese)	0.2
Ginger oleoresin	0.2
Rosemary essential oil	0.4
Gelatin solution, 2%	36.7
Collagen hydrolysate	62.5
Total	100.0

a b

Figure 3 Appearance of (a) coated (experimental sample) and (b) uncoated (control) sausage

design involved the MultiMit Expert System (registration certificate no. 2013616949). The modeling flowchart followed the scheme published in [15], with linear and nonlinear models simulating the formulation.

Table 6 shows the mass fractions of flavor compounds in the edible coating calculated with the MultiMit Expert software. A 2% gelatin solution was able to reduce the density of the final coating.

As seen from the results of the MultiMitExpert ES design and the antioxidant and antimicrobial tests, information technology in food production proved quite effective.

The technology for antimicrobial and antioxidant coating (Fig. 2 and 3) was patented in the Russian Federation (no. 2 848 749 C1: Food Film Coating for Food Products). Figure 3 compares sausages with and without coating (solidification time – 5 h).

The meat and dairy products with and without edible coatings underwent microbiological safety tests after refrigerated storage at 4°C. The storage time was one day

for unpackaged sausage (State Standard GOST 23670-2019) and three days for unpackaged soft cheese (State Standard GOST 32263-2013).

Tables 7 and 8 provide the formulations for the soft cheese and the meat products.

Figures 4 and 5 illustrate the results of the microbiological analysis of the meat and dairy products under study.

The edible coating inhibited microbial growth (Fig. 4). On storage day 8, the uncoated sausage contained by six orders of magnitude more mesophilic aerobic and opportunistic anaerobic microorganisms than the coated sausage. The experimental coating demonstrated neither *Salmonella* nor *Escherichia coli*, which confirmed its pronounced antimicrobial properties.

The coated soft cheese samples (Fig. 5) showed no signs of microbial spoilage during 14 days in a household refrigerator. The final QMAFAnM was 2×10^3, which was by two orders of magnitude lower than that of the uncoated sample. For comparison, QMAFAnM, CFU/g in the control sample was 6×10^2 on storage day 1 and 3×10^4 on storage day 14. The yeast counts in both the uncoated and coated cheese samples were 5×10^1 CFU/g whereas the mold count remained below 5×10^1 CFU/g in both groups.

The new flavor composition demonstrated a reliable antimicrobial effect when used as bioprotective coating for dairy products. Table 9 shows the antioxidant properties of the edible coating with essential oils and oleoresins. Together with Fig. 6 and 7, it also shows the induction period in the control (uncoated) and test (coated) samples of the sausages and jellied beef.

Meat products are prone to lipid oxidation during storage. The initial stage of lipid oxidation (induction) is slow. The longer the induction period, the slower the fat oxidation and sensory deterioration [2]. The oxidation rate and degree of the fat fraction can be used to determine the shelf-life stability.

The research demonstrated a 34 and 70% increase in the induction period of coated sausage and jellied beef, respectively.

The fat content of the jellied beef was 15% while that of the sausages was 25–28%. In other study [16], the induction period as a stability marker depended on the fat content and the fatty acid composition. The lower the contents of fat and unsaturated fatty acid, the higher the storage stability. As a result, the coated jellied beef was more resistant to oxidation than the coated sausages.

Table 7 Formulation for soft cheese

Ingredients	Mass fraction, %
Whole milk	97.9
Calcium chloride	0.9
Thermo-mesophilic starter	0.7
Rennet	0.4
Citric acid	0.1

Table 8 Formulation and physico-chemical indicators of sausage and jellied beef

Ingredients	Mass fraction, %
Sausage	
Mechanically deboned chicken meat	30
1st grade trimmed beef	40
Semi-fat trimmed pork	27
Whole cow's milk powder	1
Potato starch	2
Physicochemical indicators (100 g):	
protein	≥ 12.09
fat	≤ 42.42
Jellied beef	
1st grade trimmed beef	30
Beef trimmings	25
Beef sinew obtained after deboning	15
Bouillon	30
Physicochemical indicators (100 g):	
protein	≥ 9.89
fat	≤ 30.30

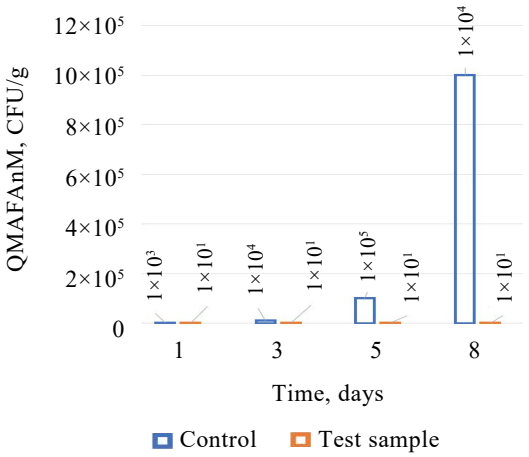


Figure 4 Microbial contamination in sausage with antimicrobial coating during refrigerated storage

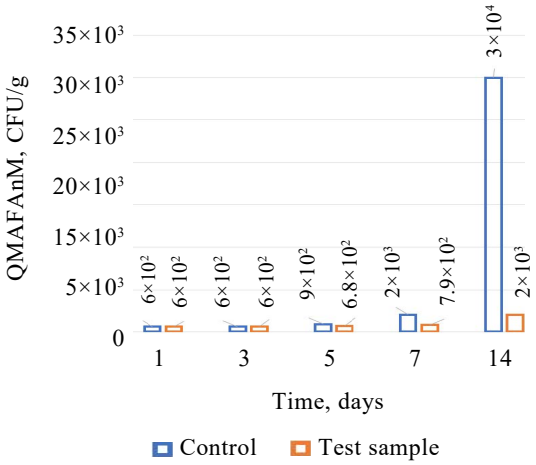


Figure 5 Microbial contamination in soft cheese with antimicrobial coating during refrigerated storage

Table 9 Antioxidant activity of meat products with and without coating

Meat product	Induction period (hh:mm)	Oxidation curve equation
Uncoated sausage (control)	13:58	$Y = –0.156x + 8.240$
Coated sausage (test sample)	20:20	$Y = –0.169x + 9.200$
Uncoated jellied beef (control)	55:29	$Y = –0.027x + 7.390$
Coated jellied beef (test sample)	94:40	–

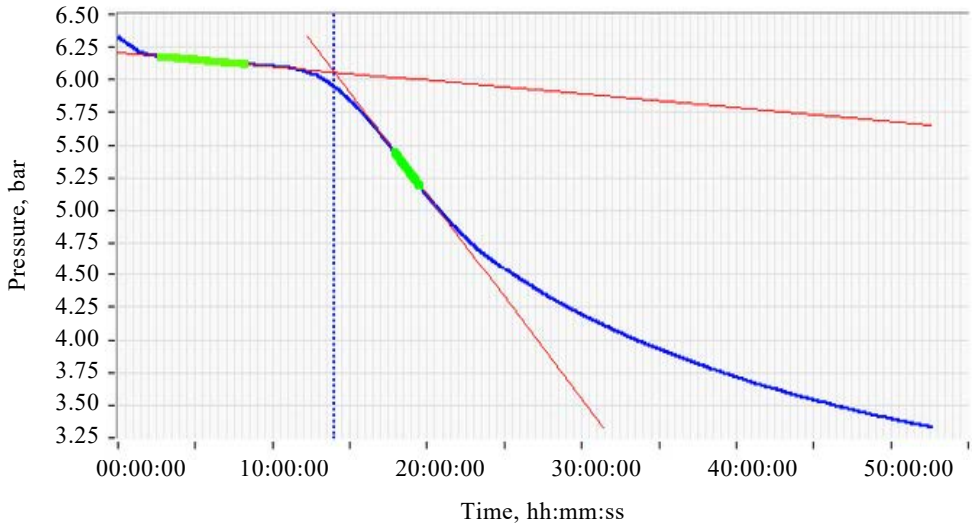


Figure 6 Induction period for uncoated sausages: Barometric curve

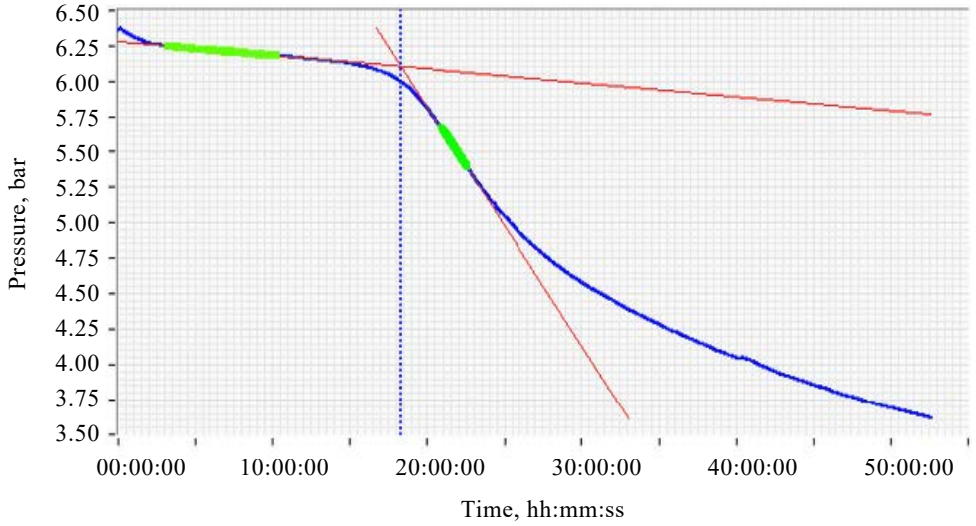


Figure 7 Induction period for coated sausages: Barometric curve

Table 10 shows the antioxidant activity of the uncoated (control) and coated (test) soft cheese samples.

The coated soft cheese samples had a longer induction period compared to the uncoated control. The increase in induction period was 44.0%.

CONCLUSION

The new edible coating technology was based on collagen-containing poultry and possessed antioxidant and antibacterial properties.

The analysis of trends carried out in the course of the study provided a scientific justification for a specific choice of food coating type. This option demonstrated a steady growth in the edible packaging segment.

Alcalase (Novozymes, Danmark) proved to be the most feasible enzyme preparation on the Russian market. This microbial-derived enzymatic preparation was applied as 0.3% of the raw material weight after swelling in water.

Table 10 Antioxidant activity of soft cheese samples with and without coating

Dairy product	Induction period (hh:mm)	Oxidation curve equation
Uncoated soft cheese (control)	34:14	$Y = –0.047x + 7.85$
Coated soft cheese (test sample)	49:43	$Y = –0.068x + 8.98$

Amino-ammonia nitrogen served as an indicator of protein hydrolysis degree; the optimal enzymatic hydrolysis time for broiler chicken skin was 5 h at 52°C.

The production technology was provided with a processing algorithm. The hybrid automated MultMeat Expert System was used to determine the optimal ratio of formula ingredients. A mix of garlic/coriander, rosemary, and ginger oleoresin essential oils gave the coating its antimicrobial and antioxidant properties.

The enzymatic hydrolysis for antibacterial and antioxidant edible food coating was provided with Technical Specifications and Technological Instructions TU/TI 10.13.15-001-52645879-2025: Edible food coating from collagen-containing raw materials.

CONTRIBUTION

All the authors were equally involved in the manuscript and are equally responsible for any potential plagiarism.

CONFLICT OF INTEREST

The authors declared no conflict of interest regarding the publication of this article.

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