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DEVISING BARRIER TECHNOLOGIES TO ENSURE THE STABILITY OF MICROBIOLOGICAL AND ORGANOLEPTIC QUALITY INDICATORS OF MEAT SEMI-FINISHED PRODUCTS

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Ways to ensure the quality and safety of meat processing products are being devised at an intensive pace. To solve these tasks, various "barriers" are used: chemical, physical, microbiological, as well as their combinations. When performing this research, a critical analysis of existing "barriers" as techniques to stabilize the quality of meat products with long shelf life was carried out. It has been revealed that the main preferences of consumers are associated with natural additives that ensure the safety of products. The introduction of modern barrier technologies is a relevant issue as it could ensure the stability of quality indicators during storage. An important task is to use natural raw materials as barriers. To this end, an analysis of the antioxidant activity of extracts from various plant-based raw materials was carried out. The results make it possible to devise technologies for creating film coatings with bioprotective properties. The dynamics of changes in the microbiological contamination of large-piece semi-finished products from beef in the process of storage at different temperatures were studied. It was found that the use of film barrier coatings leads to a restraining of the growth of microflora and has a bacteriostatic effect, which helps extend the shelf life of semi-finished products compared to control samples. The implementation of this study's results could significantly prolong the shelf life of meat semi-finished products, including at positive temperatures, without the risk of microbiological spoilage and loss of quality and functional-technological characteristics

Keywords: chilled semi-finished products, barrier technologies, extracts from plant-based preparations, bioprotective effect

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1. Introduction

The systematic growth of the pace of human life leads to an increase in the popularity of fast food products, in particular, various semi-finished products. Our monitoring of consumer demand for this category of products showed that most respondents (65 %) prefer refrigerated semi-finished products, considering them more natural and of high quality. A third of respondents are almost never interested in the conditions and terms of transportation and storage of refrigerated products. They have no idea about the requirements of regulatory documentation for quality indicators.

As a rule, meat processing enterprises are at a distance from potential consumers, which means that the actual issue is the organization of transportation of chilled products without loss of quality and safety indicators.

The most popular way to preserve the quality characteristics of meat products is the use of low temperatures during storage and transportation. In the production of chilled products, barrier technologies are most widespread for ensuring the quality and safety of products.

The theory of "barriers" is based on the joint use of several technological factors to preserve the qualitative characteristics of products, leading to a decrease in the microbiological contamination of meat products. At the same time, the barrier technology is focused on the overall quality, not only on the field of microbiological stability of the product [1, 2].

Several variants of "barriers" are actively used that can ensure the stability of the properties of meat systems during long-term storage. The most effective barriers include low initial contamination of raw meat and the use of preservative agents. Effective is to control the water activity and pH of raw materials, storage and processing temperatures. Heat treatment of raw materials and products (bringing to culinary readiness, pasteurization, and sterilization), the use of food additives of bacteriostatic action, and packaging under vacuum or using gas modified media also refer to barrier technologies. The combination of these "barriers" works most effectively.

When devising effective techniques to suppress the development of microflora, an important role belongs to scientific and technical support for the production and use of multifunctional film-forming compositions. Of particular interest in this regard are collagen proteins as the main structural element of the connective tissues of farm animals, as well as extracts from herbs that serve the carriers of natural bacteriostatic.

2. Literature review and problem statement

Research by many scientists addresses the issues related to maintaining the safety and quality of meat products. For example, work [3] considers a technique of using individual strains of lactic acid bacteria (LAB) with a significant antimicrobial effect. The organoleptic, physicochemical, and microbiological studies of samples were carried out. As a result of research, a conclusion was made to prevent the development of many strains of pathogenic microflora during storage. However, a significant drawback of the technique under consideration is changes in the organoleptic profile of the examined samples, which negatively affects the quality indicators.

Paper [4] analyzes the influence of various types of packaging on the safety of quality indicators of meat semi-finished products. The use of only physical techniques of protection against the development of contamination is ineffective and requires the introduction of preservative agents, which negatively affects consumer activity when choosing meat products.

The influence of water activity on the processes occurring in food products during storage is investigated in [5]. It is proven that the removal or binding of water in products by increasing the salt or sugar content inhibits many reactions, as well as inhibits the growth of microorganisms, thus lengthening the shelf life of products. However, this method is not suitable for all products since the removal of moisture by drying or freezing significantly affects the chemical composition and initial properties.

Article [6] reports the results of studies to substantiate the use of red leaves of thick-leaved badan as a food component as a barrier factor. The technology of a new combined meat product was evaluated using barrier technology and HACCP principles. The quality and safety of the combined meat product obtained using barrier factors such as succinic acid and an aqueous extract from the red leaves of thick-leaved badan were also investigated. The complexity of the implementation of the proposed technology refers to the inaccessibility of plant raw materials, as well as the multicomponent nature of the bio protectors used. In addition, a very specific plant-based raw material affects the organoleptic properties of finished products.

Information on various protective ingredients is systematized in [7]. Some mechanisms of their action are shown, associated with the fact that cryoprotectors inhibit negative changes in meat during freezing and storage. In addition, bioprotectors are a source of useful biologically active substances for the human body and are considered functional ingredients, antioxidants, antimicrobial substances, etc. However, the data provided are for informational purposes only. The studies do not present the properties of many plant components in relation to the possibility of restraining the development of pathogenic microflora.

The creation of edible shells with antimicrobial activity is considered in work [8]. The proposed technologies are difficult to implement and do not have a persistent antibacterial effect. As antibacterial components, the possibility of using biologically active compounds of cruciferous vegetables is being considered [9]. The proposed technology is difficult to use due to the long pre-treatment of plant-derived raw materials. The use of green tea extract as an antibacterial component [10] does not provide the desired effect and requires additional processing. It is also possible to introduce gooseberry extract [11] into the food system in order to prolong the shelf life. However, the proposed plant-based raw materials are introduced into products in the form of powders or purees, which does not contribute to the preservation of the antibacterial properties of products during storage and significantly affects the organoleptic parameters.

The possibilities of using lactic acid bacteria as bioprotective cultures for meat are also considered [12]. All the proposed techniques can significantly increase the shelf life of meat and meat products in a chilled form. However, the most interesting studies are on the combination of known techniques of protection against microbial contamination.

3. The aim and objectives of the study

The purpose of this study is to determine the effect of protective barrier coatings based on collagen with extracts from plant-based raw materials on the dynamics of microbiological contamination, the qualitative and organoleptic indicators of meat semi-finished products. This could make it possible to design an edible coating that has antibacterial properties.

To accomplish the aim, the following tasks have been set:

– to obtain collagen material;

– to study the properties of plant-based raw materials as a carrier of bioprotective properties;

– to investigate the influence of the film coating on a change in the quality and safety indicators of meat products during storage.

4. The study materials and methods

Food collagen coatings were obtained according to the technological scheme recommended by the authors of [13], including the main stages: peroxide-alkaline and enzymatic hydrolysis of collagen-containing raw materials. The immobilization of biologically active substances of CO_2 extracts from plant raw materials on the molecules of biomodified collagen proteins was carried out in accordance with the recommendations given in [14].

After a preliminary assessment of the organoleptic and bactericidal parameters of plant-based components, it is proposed to use CO_2-extracts from ginger, St. John's wort, green tea, calendula, and red pepper (manufactured by Grumat, Russia) for inclusion in the formulations of film-forming compositions.

In parallel, studies were conducted on extracts obtained by aqueous extraction. The preparation of extracts was carried out according to the manufacturer's recommendations.

The dosage of plant-based raw materials was carried out in accordance with the manufacturer's recommendations, taking into consideration the sensory and organoleptic characteristics of the finished product.

The organoleptic indicators of meat semi-finished products were determined according to GOST 9959-2015 "Interstate standard. Meat and meat products. General conditions for organoleptic evaluation. The method is based on the use of information obtained as a result of the analysis of the perception of the sense organs: vision, hearing, smell, touch, and taste."

Studies of the antioxidant activity of extracts from plant-based raw materials were conducted at the analytical liquid chromatographer "Tsvet Yauza" with amperometric and conductometric detectors according to the procedures recommended by GOST R 54037.

The effect of a film coating on the microbiological contamination and qualitative indicators of large-piece semi-finished products was studied according to the following research scheme.

The application of a barrier coating on large-piece semi-finished beef products was carried out by spraying a dispersion. Semi-finished products processed in this way were packed in a standard plastic bag and stored for 35 days at temperatures from +4 to +20 °C. Product studies were carried out immediately after manufacture (background) and then with an interval of 10 days.

The study of the microbiological indicators of large-piece semi-finished products from beef in the process of storage was carried out at the research laboratory of AO "Almaty Technological University" (Kazakhstan) in accordance with GOST 54354.

5. Results of studying the effect of film coatings on the microbiological contamination of meat products during storage

5. 1. Fabrication of food-grade collagen coatings

Using known data on the structure of antioxidants in the composition of plant-based raw materials and the structure of collagen, we used computer simulation employing the HyperChem 8.0 software, developed by Hypercube, Inc., USA [1 5], to build a hypothetical model of a collagen coating with biologically active components (Fig. 1).

The resulting model makes it possible to visually assess the structure of the proposed antibacterial coating and the degree of interaction of the base with the components of the system.

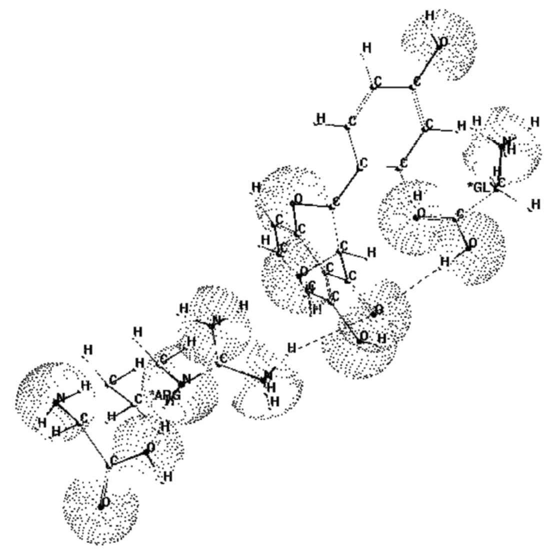

Fig. 1. Hypothetical model of interaction of flavonoid with glycine and arginine in the structure of collagen hydrolysis products

5. 2. Studying the properties of plant-based raw materials

To assess the effectiveness of the use of selected aqueous and CO_2 extracts, studies of antioxidant activity were conducted. The results of the research are shown in Fig. 2.

The biocidal properties of CO_2-extracts and aqueous extracts from plant-based raw materials were also studied by investigating the growth retardation of microorganisms; the data are illustrated in Fig. 3.

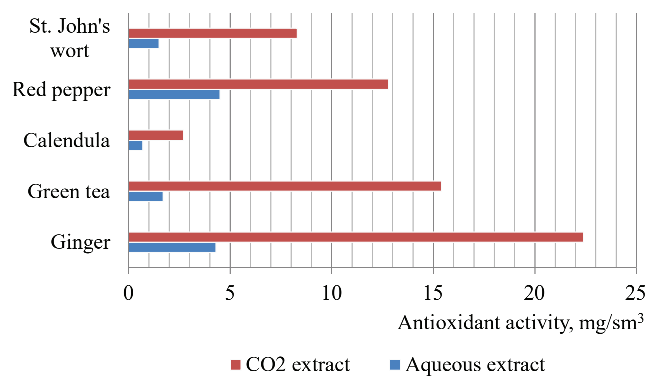

Fig. 2. Antioxidant activity of plant-derived extracts

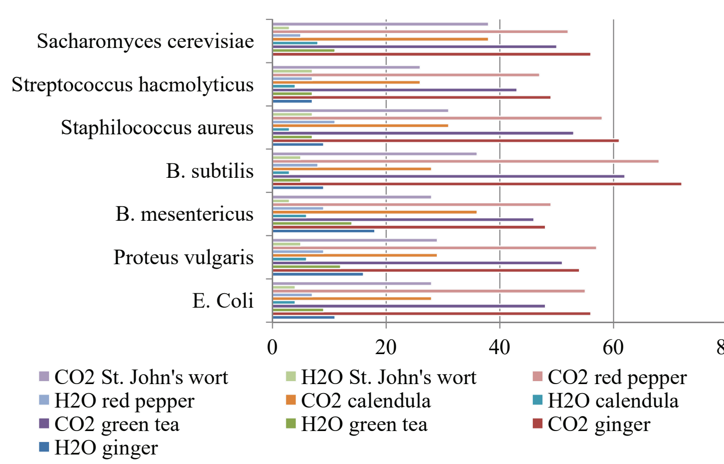

Fig. 3. Zones of growth retardation of microorganisms, mm

Aqueous and CO_2-extracts are able to restrain the growth of pathogenic microflora, which makes it possible to recommend them as natural antibiotics.

5. 3. Studying the effect of a coating on the quality and safety indicators of meat products

Microbiological studies were carried out in the starting raw material, on 10, 20, and 30 days under both storage modes: the results are given in Tables 1, 2.

Studies were also conducted on changes in the organoleptic assessment of the quality of packaged products: the results of the studies are givenin Table 3.

Both the control and prototype in the first ten to fifteen days did not differ significantly in terms of organoleptic indicators. After twenty days of storage of the control and experimental semi-finished products, differences in organoleptic indicators are visible.

Table 1

The dynamics of microflora content during storage of large-piece semi-finished products at a temperature of +20 °C

Indicator	Measurement unit	Standard [technical regulations of the customs union 034/2013]	Change in the content of microorganisms during storage, day							
			control				experiment			
			Starting	10	20	30	Starting	10	20	30
QMAFAnM	CFU/g, no more	$1.0 \cdot 10^4$	$4.8 \cdot 10^2$	$3.4 \cdot 10^3$	$1.0 \cdot 10^4$	$>3.0 \cdot 10^5$	$1.2 \cdot 10^2$	$1.8 \cdot 10^3$	$7.3 \cdot 10^3$	$1.3 \cdot 10^4$
E. coli group bacteria	not allowed	2	0.01 g	not detected	not detected	not detected	not detected	not detected	not detected	not detected
L. monocytogenes	not allowed	25 g	not detected	not detected	not detected	not detected	not detected	not detected	not detected	not detected
Pathogenic, including salmonella	not allowed	25 g	not detected	not detected	not detected	not detected	not detected	not detected	not detected	not detected

Table 2

The dynamics of microflora content during storage of large-piece semi-finished products at a temperature of +4 °C

Indicator	Measurement unit	Standard [technical regulations of the customs union 034/2013]	Change in the content of microorganisms during storage, day							
			control				experiment			
			Starting	10	20	30	Starting	10	20	30
QMAFAnM	CFU/g, no more	$1.0 \cdot 10^4$	$4.8 \cdot 10^2$	$9.6 \cdot 10^2$	$3.3 \cdot 10^3$	$>9.9 \cdot 10^5$	$1.2 \cdot 10^2$	$7.1 \cdot 10^2$	$1.1 \cdot 10^3$	$1.5 \cdot 10^3$
E. coli group bacteria	not allowed	2	0.01 g	not detected	not detected	not detected	not detected	not detected	not detected	not detected
L. monocytogenes	not allowed	25 g	not detected	not detected	not detected	not detected	not detected	not detected	not detected	not detected
Pathogenic, including salmonella	not allowed	25 g	not detected	not detected	not detected	not detected	not detected	not detected	not detected	not detected

Table 3

Organoleptic studies of large-piece semi-finished products

Semi-finished product name	Type of packaging	Reaction with copper sulfate	Appearance, color, smell	Clarity and aroma of broth
1	2	3	4	5
Storage, day 0				
Scapular part	Control / Experiment	Transparent broth→fresh meat	In the cut, the meat is dense, elastic; the deepening formed when pressing with a finger is quickly aligned. The smell is specific, characteristic of each type of fresh meat	Transparent, aromatic
Storage, day 10				
Scapular part	Control	Small amounts of flakes→meat of questionable freshness	In the cut, the meat is less dense and less elastic; the deepening formed when pressing with a finger is leveled slowly (within 1 minute), the fat is soft, the defrosted meat is slightly loosened. The smell is slightly sour with a hint of mustiness	Transparent or cloudy with a slightly unpleasant odor
	Experiment	Transparent broth→fresh meat	In the cut, the meat is dense, elastic; the deepening formed when pressing with a finger is quickly aligned. The smell is specific, characteristic of each type of fresh meat	Transparent, aromatic
Storage, day 20				
Scapular part	Control	Cloudy broth→stale meat	In the cut, the meat is flabby; the deepening formed when pressing with a finger does not even out, the fat is soft, the defrosted meat is loose, salted. The smell is putrid	Cloudy with a lot of flakes and a pungent unpleasant odor
	Experiment	Transparent broth→fresh meat	In the cut, the meat is dense, elastic; the deepening formed when pressing with a finger is quickly aligned. The smell is specific, characteristic of each type of fresh meat	Transparent, aromatic

Continuatuin of Table 3

1	2	3	4	5
Storage, day 30				
Scapular part	Control	Cloudy broth→stale meat	–	–
	Experi-ment	Transparent broth→fresh meat	In the cut, the meat is dense, elastic; the deepening formed when pressing with a finger is quickly aligned. The smell is specific, characteristic of each type of fresh meat	Transparent, aromatic
Storage, day 35				
Scapular part	Control	Cloudy broth→stale meat	–	–
	Experi-ment	Cloudy broth→meat of doubtful freshness	In the cut, the meat is less dense, the deepening formed when pressing with a finger slowly aligns. The smell is specific, characteristic of each type of fresh meat	Transparent, with a small amount of flakes

6. Discussion of results of studying the influence of collagen coatings on the safety and quality indicators of products

The choice of CO_2-extracts from medicinal plants and spices as sources of biologically active substances is predetermined by their unique physicochemical properties and antibacterial action. In terms of antibacterial effect, many plant-based raw materials outperform similar well-known products: naturally-identical flavors (obtained chemically) and natural (oil, alcohol) extracts. In addition, CO_2-extracts are actively used in the production of meat products as the flavoring and aromatic additives.

The dosage of application to the collagen emulsion was selected according to the manufacturer's recommendations. The dosage of CO_2-extracts is selected from 0.1 to 0.5 %. The optimal dosage of plant-based extracts is considered to be 0.25 % since a lower dosage does not provide sufficient sensory and bactericidal characteristics, and a high one gives the product a sharp unpleasant odor. An optimum for the dosage of aqueous extracts is 1–5 %.

The greatest antioxidant activity is possessed by extracts from ginger, green tea, and red pepper (Fig. 2). At the same time, water extracts contain noticeably less biologically active substances.

Fig. 3 demonstrates that the aqueous extracts from plant-based raw materials slightly delay the development of pathogenic microflora; in addition, their introduction into the collagen dispersion leads to a change in the viscosity of the system and an increase in the period of formation of the film coating. Thus, the results obtained make it possible to predict the use of film coatings with CO_2-extracts as a technological barrier in relevant specific technologies. The introduction of CO_2-extracts into dispersion systems based on collagen proteins does not reduce their film-forming ability.

The microbiological studies were carried out using the starting raw materials, on days 10, 20, and 30 under both storage modes; the results are given in Tables 1, 2. It follows from the above data that the meat raw materials used in the experiments, according to microbiological indicators, corresponded to the standards for fresh meat. The total number of microorganisms is not more than $5.0 \cdot 10^2$; E. coli group bacteria in 0.1 g were not detected; pathogenic microorganisms, including salmonella, in 25 g were not detected.

Samples coated with a film material with the introduction of an CO_2-extract of red pepper (storage mode +20 °C) on day 20 had lower microbiological contamination (by 1.4 times) compared to control samples (packaging under vacuum).

Samples coated with a film material with the introduction of an CO_2-red pepper extract (storage mode +4 °C) had lower microbiological contamination (3.0 times lower) compared to control samples.

On day 20 of storage, in the control samples of semi-finished products (storage mode +20 °C), an excess of microbiological indicators provided for by the requirements of the Sanitary Rules and norms for chilled meat was recorded. At the same time, in the prototypes, the shelf life was slightly less than 30 days.

When storing semi-finished products at +4 °C, the shelf life of the control samples of vacuumed semi-finished products was 25 days, while that of prototypes – 35 days (on day 35 of storage, QMAFAnM was $8.4 \cdot 10^3$).

According to the results of microbiological studies, it was found that the use of film barrier coatings leads to a restraining of the growth of microflora and has a bacteriostatic effect, which helps prolong the shelf life of semi-finished products compared to control samples.

Our analysis of organoleptic studies (Table 3) shows that the samples in the first ten to fifteen days did not differ significantly in organoleptic indicators. After twenty days of storing the control and experimental semi-finished products, differences are visible, which reach up to 1.2 points in the point estimate.

Thus, film coatings with CO_2-extracts from plant-based raw materials can preserve the freshness of large-piece semi-finished products from beef for up to 35 days at a storage temperature not exceeding 4 °C.

Priority research areas are the study of changes in the sensory and color characteristics of semi-finished products over the entire shelf life.

7. Conclusions

1. Collagen emulsion has been obtained. The time of formation of a dense film with a thickness of 1–3 mm is 5–10 min. Applying the emulsion to the surface of meat semi-finished products can prevent moisture loss and oxidation of the components.

2. We have selected plant components containing biologically active substances with antibacterial properties. The antioxidant activity of plant-based raw materials was studied. CO_2-extracts have the greatest activity in comparison with aqueous ones. In the direction of increase, the activity of aqueous and CO_2-extracts can be represented in the following form, mg/cm^3: calendula – 0.7–2.7; St. John's wort –

1.5–8.3; green tea – 1.7–15.4; red pepper – 4.5–12,8; ginger – 4.3–22.4, respectively. The use of extracts in the composition of an edible collagen coating can prevent the development of pathogenic microflora and oxidative spoilage of meat.

3. The shelf life of chilled products and changes in organoleptic parameters during storage were studied. At a storage temperature of +4 °C, the prototype meets all the requirements of regulatory documentation within 35 days. At a storage temperature of +20 °C – 20 days. Coating the meat semi-finished products with collagen emulsion, which has bioprotective properties, provides an increase in shelf life at low-positive and positive temperatures by 10 days.

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