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EDIBLE FILM-FORMING COATING WITH CO_2-EXTRACTS OF PLANTS FOR MEAT PRODUCTS

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Abstract. In this work, a film-forming coating for natural semi-finished pork meat has been developed, which has barrier properties against microbial flora and free oxygen radicals. Polysaccharides such as agar, gelatin, cornstarch, and citrus pectin were used as components of a film-forming coating, as well as CO_2-extracts of parsley and ginger. It has been found that the most effective is a coating with the following composition: agar – 0.25%, citrus pectin – 0.5%, citric acid – 0.5%, CO_2-extract of parsley or CO_2-extract of ginger – 0.1%. This coating prolongs the shelf life of natural semi-finished pork meat at a storage temperature (–1…+1)°C for 2 days compared with the traditional technology.

Studying the effect of the film-forming coating developed on the organoleptic properties of meat has shown that on the 7th day of storage at a temperature (–1…+1)°C, there were no signs of spoilage like putrid smell, greenish stain, and sliminess that were observed in the samples without coating. The study of the effect of the coating on the microbiological parameters of the meat has shown that the best microbiologcal stability that does not exceed the allowable values after 7 days of storage at a storage temperature (–1…+1)°C is that of the sample covered with the film-forming coating with a CO_2-extract of parsley. The study of the effect of the film-forming coating on the physical and chemical properties of meat has shown that peroxide number of its fat content is lower by 0.007% of iodine, and the acid number of its fat content is 0.39 mg KOH/kg of fat lower compared to the values of these parameters in the meat samples without coating. Besides, during storage, the mass loss in the meat samples covered with the coating developed was about 6 % less, thus reducing drying loss.

Keywords: edible coating, CO_2-extracts of plants, semi-finished meat products.

ЇСТІВНЕ ПЛІВКОУТВОРЮВАЛЬНЕ ПОКРИТТЯ З CO_2-ЕКСТРАКТАМИ РОСЛИН ДЛЯ М'ЯСНИХ ПРОДУКТІВ

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Анотація. У роботі розроблено плівкоутворювальне покриття для натуральних напівфабрикатів із м'яса свинини, що володіє бар'єрними властивостями до мікробної мікрофлори і вільних радикалів кисню. У якості компонентів плівкоутворювального покриття досліджували наступні полісахариди: агар, желатин, крохмаль кукурудзяний, пектин цитрусовий, а також використовували CO_2-екстракти петрушки та імбиру. Встановлено, що найбільш ефективним є покриття з наступним складом: агар – 0,25%, пектин цитрусовий – 0,5%, лимонна кислота – 0,5%, CO_2-екстракт петрушки або CO_2-екстракт імбиру – 0,1%, оскільки це покриття подовжує термін зберігання натуральних напівфабрикатів із м'яса свинини при температурі зберігання (–1…+1) °С на 2 доби у порівнянні з традиційною технологією.

Дослідження впливу розробленого плівкоутворювального покриття на органолептичні властивості м'яса показало, що у нього на 7 день зберігання при температурі зберігання (–1…+1)°С були відсутні ознаки псування, такі як гнилісний запах, зеленкуватий відтінок та ознаки ослизнення, що спостерігались у зразків без покриття. Дослідження впливу розробленого плівкоутворювального покриття на мікробіологічні показники м'яса показало, що найкращі результати мікробіологічної стабільності, які не перевершують допустимі значення на 7-ий день зберігання при температурі зберігання (–1…+1) °С відповідають зразку, на яке нанесено плівкоутворювальне покриття з CO_2-екстрактом петрушки. Дослідження впливу розробленого плівкоутворювального покриття на фізико-хімічні властивості м'яса показало, що його пероксидне число нижче на 0,007%, а кислотне число нижче на 0,39 мг КОН у порівнянні до значень цих показників у зразках м'яса без покриття. Також втрати маси зразків м'яса з розробленим плівкоутворювальним покриттям під час зберігання зменшились на 6%.

Ключові слова: їстівне плівкоутворювальне покриття, CO_2-екстракти рослин, м'ясні напівфабрикати.

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Introduction. Formulation of the problem

As healthy lifestyles are becoming more and more popular, one of the trends in food industry is the development and production of safe natural food retaining its freshness and quality when stored as long as possible [1].

Meat raw material easily spoils due to its chemical composition, and meat products are sensible to environmental hazards including contamination by bacteria and fungi during processing and storage. That is why, meat products need to be protected from damage during preparation, storage, and sale in order to extend their shelf life and improve quality. Most microorganisms that contaminate meat products are pathogens that can cause serious health problems for consumers, especially if these products are processed and distributed in inappropriate conditions. Besides, there can be an undesirable reaction that modifies the smell, taste, color, and texture of fresh food [2].

Traditional canning technologies, such as heat treatment, pickling, or souring, that have long been used in food industry to prevent damage and growth of pathogenic microorganisms in food, often result in unacceptable loss of its nutritional value [1]. However, new strategies in preservation methods provide more effective protection of food without changing its organoleptic and nutritional properties. Today, the problem of storing meat and meat products for quite a long time is solved by combining the refirigeration of meat with other methods of its treatment that affect microbial flora. In particular, vacuum and modified gas environment, intelligent edible systems, new improved packing materials and coatings are used to this end [3,4].

This is especially true for edible antimicrobial films and coatings that researchers and food industry have been interested in over the past ten years as they can increase the safety, quality, and functionality of food products and inhibit the growth of unwanted microorganisms during storage and transportation [3].

Analysis of recent research and publications

Edible coatings belong to a unique category of packaging materials that are different from ordinary packaging as they can be consumed together with the packaged product. Food films and coatings are obtained from biological materials such as polysaccharides, proteins, lipids, and their derivatives. Films and coatings act as a barrier against moisture, gases, light. They protect the product and prolong its shelf-life. An edible coating is a thin layer of an edible material functioning in the form of a covering that, on its formation, can be applied to a food product. It is applied, in the form of a solution, directly to the product by spraying or immersion. Edible coatings play an important role in the storage, transportation, and distribution of food, as they create a modified environment that limits the transfer of gases (O_2, CO_2) and is a barrier to the transfer of aromatic compounds. Coatings prevent the development of septic microbian flora and moisture transfer [5].

A wide variety of antimicrobial agents for food coating compositions has been described, with a view to their application to fresh products [6]. Some are derived from natural sources and traditionally used as food additives, they have a commonly recognized Safety Label (Generally Recognized as Safe) (GRAS). Their antimicrobial action is due to the content of organic acids, enzymes, bacteriocin, and derivatives of plant products such as thymol and carvacrol essential oils [2]. The choice of the most appropriate antimicrobial agent is important, as some relevant aspects should be considered, in particular, good interaction between the polymer matrix and the active agent, the effect of the coating on the product, and its effectiveness against the target microorganisms.

An antimicrobial edible coating for chicken meat products has been developed containing a mustard extract, apple or acetic acid in its k-carrageenan-based and chitosan-based biopolymer matrix. Coatings like this caused a decrease in the viability of five different *L. monocytogenes* strains and in *Campylobacter* bacteria in samples of meat products that had been vacuum-packed at a storage temperature of 4C [7].

Other antimicrobial agents have been suggested for the production of new protein-based edible coatings active against *L. monocytogenes*. As an effective antimicrobial agent added to edible coatings based on sodium alginate and sorbitol, an extract of caraway (Thymus vulgaris L.) and propionic acid have been selected. These active substances prolonged the shelf-life and safety of fresh chicken meat, adversely affecting the growth of the microorganisms *E. coli* and *L. Inocua* [8].

A mixture of lactic acid, nicine, and lauric acid arginate was added in different concentrations to the oleic acid nano emulsion as part of the wax starch food coating to reduce the growth of *Brochotrix thermosacta*, *L. monocytogenes* and *Micrococcus luteus* in pork meat [9].

Pollution with Salmonella was reduced in pieces of ham by using antimicrobial coating based on low-fat soy flour, lactoperoxidase extracted from cow's milk, xanthan glycerol, and glycerin [10].

Particular attention should be paid to such highly effective antimicrobial and antioxidant agents in food coatings as CO_2-extracts of plants. A CO_2-extract is a concentrated form of biologically active substances of plants having a high level of target activity.

Biologically active substances, in some amounts contained in different plants, play a huge role in maintaining and stabilizing important biochemical and physiological processes of the human body. It is known that many biologically active components are present in plants in small quantities, therefore in some cases there is a need for their selection and / or concentration. And one of the ways to solve this problem is extraction, which is widely used in modern industry.

A CO_2-extract is a concentrate of a plant's own substances, without foreign impurities, solvents, and water, obtained with carbon dioxide as a solvent. CO_2-extracts compared with extracts obtained with other solvents have the following advantages [11]:

- they preserve, to the highest possible extent, all biologically active substances and are absolutely natural and environmentally friendly products;

- they are sterile themselves and produce a bactericidal effect on the microflora of the product they are introduced in;

- convey the taste and aroma of the product from which they were obtained;

- the shelf life of the extract in a sealed packaging is not less than 2 years;

- contain a lot of natural preservatives and antioxidants that aid the preservation of the product, which excludes the use of synthetic preservatives;

- CO_2-extracts are ready-to-use products for direct use in various applications and do not require further processing to remove residues of the solvent.

CO_2-extracts are widely used in non-alcoholic, distillery, confectionery, meat, fish, and canning industries [12].

The results of the composition of edible film-forming coatings for meat products developed prove how necessary it is to create their more versatile variants that would have a wider range of effects, affect different groups of microorganisms and fungi, and combine an antimicrobial action of the coating with an antioxidant one. Micro concentrations of CO_2-extracts of plants can effectively provide such an effect.

The purpose of this work was to develop a film-forming edible coating for extending the shelf life of natural cooled semifinished meat products.

Research tasks:

– to establish an effective composition of the film-forming edible coating matrix;
– to find the appropriate CO_2-extracts for film forming coatings of natural semi-finished pork meat products;
– to establish microbiological, organoleptic, and physico-chemical parameters of semi-finished pork meat products stored with the use of a film-forming coating with CO_2-extracts.

Research Materials and Methods

The experimental part of the research work was carried out in the production laboratory of the meat processing enterprise LLC TITAN (Odesa region, Kilia) and in the laboratory of the Department of Meat, Fish, and Seafood Technology of Odessa National Academy of Food Technologies.

In the work, CO_2-extracts of parsley and ginger (produced by Company Karawan LTD, Russia, Krasnodar) were used. The parsley CO_2-extract is an oily mass with wax-like inclusions, of a greenish-brown color, with a pronounced characteristic odor, its antioxidant activity is 10 mg/cm^3. The ginger CO_2-extract is a brown, liquid oily mass with wax-like inclusions, with a sharp taste and a specific smell of ginger, with soft and spicy notes, its antioxidant activity is 8 mg/cm^3.

As gelators, the following polysaccharides were used: agar (produced by Foodchem International Corporation, China), citrus pectin high-etherified (manufactured by Shanghai ZZ New Material Tech. Co., Ltd., China), gelatin (manufactured by Dalian Launcher Fine Chemical Co., Ltd., China), corn starch (manufactured by LLC "August-Kiy", Ukraine).

As a meat raw material, natural semi-finished bacon pork (produced by TITAN Ltd, Odesa region, Kilia) was used.

The film-forming coating was prepared by combining polysaccharide solutions. The agar solution was prepared by dissolving a certain weighed portion of polysaccharide in 100 cm^3 of water and heating the solution to a temperature of 100°C, followed by cooling to the gelation temperature. The citrus pectin solution was prepared by dissolving a certain amount of polysaccharide in 100 cm^3 of water at a temperature of 50°C with subsequent heating to a temperature of 100°C and addition of a certain concentration of citric acid at the end and subsequent cooling to the gelation temperature. The gelatin solution was prepared by dissolving a certain amount of polysaccharide in 100 cm^3 of water at a temperature of 90°C, followed by cooling to the gelation temperature. The corn starch solution was prepared by dissolving a certain amount of polysaccharide in 100 cm^3 of room temperature water and heating the solution to a temperature of 100°C, followed by cooling to the gelation temperature [13].

The gelation temperature is the temperature of the polysaccharide solution that indicates its transition from the liquid state to more viscous. At this temperature, the polysaccharide solution is homogeneous and fluid and is easily applied to a solid surface. The gelation temperature was measured with a thermometer.

The organoleptic characteristics of the film-forming coating were determined after its application to a glass plate and exposure for 24 hours at room temperature. The organoleptic parameters visually identified were transparency, durability, fragility, elasticity, and thinness.

The active acidity (pH) of the solution was determined by the potentiometric method according to the generally accepted procedure [14].

The dynamic viscosity of the solution was determined with a Happler viscometer of precision type and calculated by the formula (1).

The viscosity index was determined as the ratio of the solution's dynamic viscosity after gelling and the dynamic viscosity of the water. It was calculated by the formula (2).

$$\eta = \tau \times (\rho_1 - \rho_2) \times K \quad (1)$$

$$V_i = \eta / \eta_w \quad (2)$$

η – dynamic viscosity, sP; V_i – viscosity index; τ – ball falling time, c; ρ_1 – the density of a ball, g/cm^3; ρ_2 - liquid density at a measured temperature, g/cm^3; K –

constant of a ball, sP×cm^3/g×c, η_w – dynamic viscosity of water, sP.

The film-forming coating was applied to semi-finished pork meat by immersion. The organoleptic characteristics of natural semi-finished bacon pork were visually determined by describing the appearance, color, and smell. The general bacterial contamination and the coliform bacteria, the fat acidity value, and the fat peroxide value were determined according to the generally accepted method [14]. Losses of meat after heat treatment of samples in water at a temperature of 100°C for 30 min. were determined according to the generally accepted method [14].

At the first stage of the research, to determine the effective composition of the film-forming coating, the properties were analyzed of a 1% solution of individual components based on the polysaccharides under study (agar, citric pectin, gelatin, corn starch). The gelation temperature and active acidity (pH) of the solution were determined, as well as the organoleptic characteristics of the film-forming coating that appeared after the gel formation of the solution.

At the second stage, variants are composed of the complex basis of the film-forming coating matrix from the selected polysaccharides. Table 1 shows the content of the components of edible coating matrix samples (the rest of the composition is water).

Table 1 – Variants of the complex basis of the film-forming coating matrix

Sample of a matrix variant	Agar, %	Citric pectin, %	Citric acid, %
1	1	1	-
2	0.25	0.25	-
3	0.5	1	1
4	0.25	0.5	0.5

The following propeties of the samples of matrix variants were determined: gelation temperature, organoleptic characteristics of the film, active acidity (pH) of the solution, dynamic viscosity of the solution after gel formation, viscosity index.

At the next stage of the research, CO_2-extracts were selected based on their antioxidant activity and organoleptic characteristics according to the literature [15]. As the manufacturer recommended, 0.1% of the selected CO_2-extracts was added to the optimum matrix variant of the film-forming coating for natural semi-finished pork meat products.

The following samples were studied to determine the shelf life of natural semi-finished pork meat products with the edible film-forming coating of the newly-developed composition applied by the method of immersion: 1 – meat without coating, 2 – meat with a polycomponent basis without a CO_2-extract, 3 – meat with a polycomponent basis and a CO_2-extract of ginger, 4 – meat with a polycomponent basis and a CO_2-extract of parsley.

In the process of storage at (–1…+1)°C, the following parameters were determined: organoleptic, total bacterial contamination, fat acidity value, fat peroxide value, heat treatment losses.

Results of the research and their discussion

When choosing the effective composition of the polycomponent basis for the matrix of the film-forming coating, the properties were analyzed of a 1% solution of the individual components based on the investigated polysaccharides (agar, citric pectin, gelatin, corn starch) that could potentially form the basis of the matrix. The results of the studies are shown in Table 2. The solutions' gelation temperature was taken into account, because when a liquid coating with a temperature above 45°C is applied to the surface of semi-finished meat, the surface layer proteins can be denatured. Since the gelation temperature of a 1% solution of gelatin and wheat starch was, respectively, 60°C and 90°C, these polysaccharides were excluded from further studies.

Table 2 – Parameters of a 1 % solution of polysaccharides for the basis of a film-forming coating matrix

1% solution of polysaccharide	Parameters		
	Active acidity (pH)	Gelation temperature, °C	Organoleptic characteristics of the coating
Agar	6.4±0.26	38±1.06	transparent, elastic, durable
Gelatin	7.2±0.43	60±0.84	transparent, elastic, fragile
Corn starch	6.8±0.58	90±1.12	opaque, viscous, fragile
Citric pectin	5.2±0.17	34±1.59	transparent, elastic, fragile

The next subject of the research was the organoleptic parameters of compositional combinations of the polycomponent coating matrix (Table 1) on the basis of agar, citric pectin, and citric acid. The results of the studies are shown in Table. 3. The preference was given to multicomponent bases as they were transparent, elastic, thin, and durable. The index of viscosity of the investigated samples of the polycomponent composition of the matrix has been established, and the sample has been preferred with the largest dynamic viscosity index for better sticking to the surface of the meat after immersion. The optimum composition of the multicomponent matrix basis for a film-forming coating has been found in sample 4: 0.25% of agar, 0.5% of citric pectin, 0.5% of citric acid, and the rest of the composition is water.

Table 3 – Parameters of the variants of the complex basis of the film-forming coating matrix

Sample of the matrix variant	Gelation temperature, °C	Active acidity (pH)	Organoleptic characteristics of the coating	Viscosity index V_i
1	38±0.72	6.1±0.17	transparent, durable, viscous	2.1±1.45
2	36±1.03	5.4±0.03	transparent, elastic, durable	3.5±0.95
3	36±0.88	4.7±0.09	transparent, elastic, durable	3.8±1.38
4	36±1.15	5.0±0.21	transparent, elastic, durable, thin	7.2±1.13

Data from the literature determined the choice of the CO_2-extract of parsley and the CO_2-extract of ginger. The CO_2-extract of parsley has a high antioxidant activity due to the presence of plant phytoestrogens that protect the product from harmful environmental factors and prevent the formation of free radicals. The phytoestragenes of the CO_2-extract of parsley are similar in their chemical composition to the protein structure of the meat, which determines its biocompatibility with meat products. The CO_2-extract of ginger has a pronounced antiseptic effect.

Then, variants were studied of the edible film-forming coating for natural semi-finished pork meat. To chosen sample 4 of the film-forming coating matrix the CO_2-extract of parsley and CO_2-extract of ginger were added. The results of studying the natural semi-finished pork meat samples during their storage at a temperature of (–1…+1)°C, some of which were covered with different film-forming coatings, are shown in Table 4 (indicators of general bacterial contamination), Table 5 (organoleptic characteristics), Fig. 1 (fat acidity value), Fig. 2 (fat peroxide value), Fig. 3 (pH – active acidity), Fig. 4 (mass loss of the meat after heat treatment).

Table 4 – General bacterial contamination of natural semi-finished pork meat product during storage at a temperature of (–1…+1)°C

Indicators	Standard	Sample 1			Sample 2			Sample 3			Sample 4		
		day 1	day 3	day 7	day 1	day 3	day 7	day 1	day 3	day 7	day 1	day 3	day 7
The amount of mesophilic aerobic and facultative anaerobic microorganisms, colony-generating items per 1 g of the product	not more than $5×10^5$	$4.1×10^4$±42.36	$9.6×10^4$±55.36	$2.4×10^5$±35.92	$1.8×10^4$±62.04	$1.0×10^5$±23.15	$6.0×10^5$±33.18	$8.5×10^3$±12.05	$4.0×10^5$±63.28	$5.8×10^5$±65.68	$1.2×10^4$±78.14	$4.1×10^4$±54.36	$1.0×10^5$±31.13
E. coli group bacteria	not allowed	no	no	yes	no	no	yes	no	no	no	no	no	no

Table 5 – Changes in the organoleptic characteristics of natural semi-finished meat pork product samples during storage at (–1…+1)°C

Sample	Organoleptic characteristics		
	Appearance	Color	Smell
1 day			
1	The surface is clean, not air-dried, without sliminess, without fringe, the edges are even	Pale red	Good-quality meat, without any foreign smell
2	The surface is clean, glossy, not air-dried, without sliminess, without fringe, the edges are even		
3			
4			
3 day			
1	The surface is clean, not air-dried, without sliminess, without fringe, the edges are even	Pale red	Good-quality meat, without any foreign smell
2	The surface is clean, glossy, not air-dried, without sliminess, without fringe, the edges are even		
3			
4			
7 day			
1	The surface has pronounced signs of sliminess	Pink with greenish tinge	The smell of low-quality meat, putrid
2	The surface is clean, glossy, not air-dried, without sliminess, without fringe, the edges are even	Pale red	Meat with a slight foreign smell
3			Good-quality meat, without any foreign smell
4			

The results of the microbiological research prove that the value of general bacterial contamination of sample 1 is much higher than that of samples 3 and 4 on the 1st day. This is due to the death of some microorganisms under the influence of CO_2-extracts of plants. During further storage, there is a slow increase in the number of mesophilic aerobic and facultative anaerobic microorganisms in the experimental samples with protective compositions. However, the values of the microbiological parameters of the sample with the CO_2-extract of parsley, unlike other samples, do not exceed the allowable values for natural semi-finished pork meat products on the 7th day of storage, nor bacteria of the *E. coli* group are found.

The results of studying the organoleptic parameters have shown that sample 1 without coating after 7 days of storage had a putrid smell, greenish stain, and signs of sliminess, and samples 3 and 4 with a polycomponent coating after 7 days of storage had no signs of deterioration.

Experimentally, it has been found that the application of polycomponent coatings 3 and 4 to the surface of the samples positively effects on the stabilization of the lipid fraction of semi-finished products after 7 days of storage. The fat peroxide value remains lower by 0.007% of iodine than in samples 1 and 2. The fatty acid content is lower by 0.39 mg KOH per 1 kg of fat for samples 3 and 4 as compared to samples 1 and 2.

The change in the active acidity (pH) of all samples is due to autolytic changes in the meat during storage, but it should be noted that it is in sample 1 without a coating where these changes are the most noticeable.

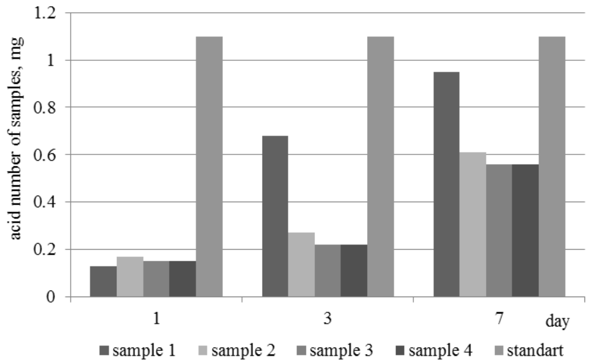

Fig. 1. Fat acid value of the samples, mg

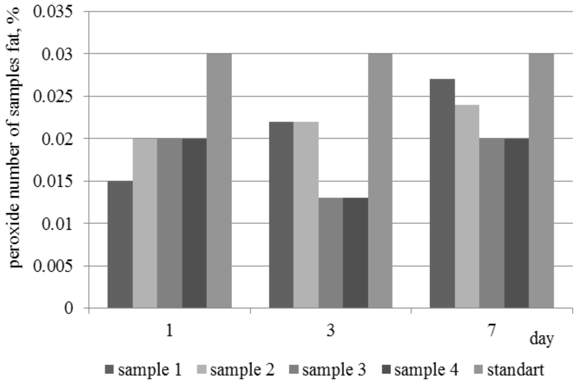

Fig. 2. fat peroxide value of the samples, %

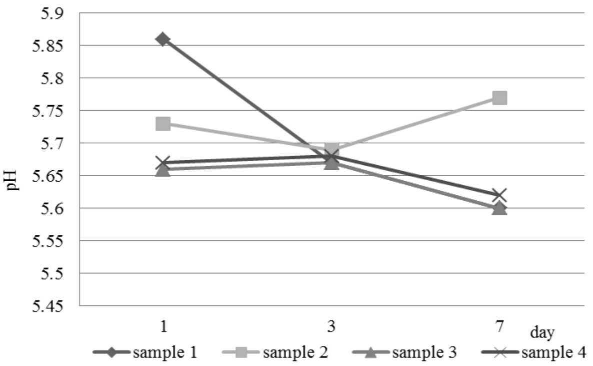

Fig. 3. pH value of the samples

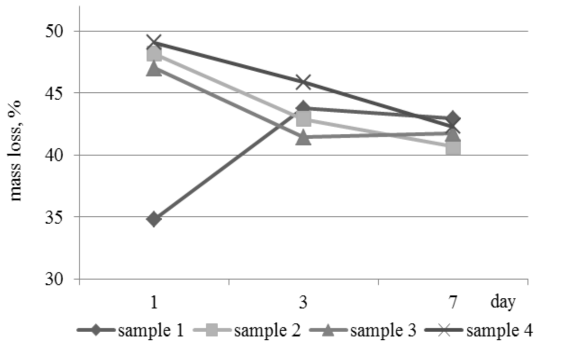

Fig. 4. Mass loss after heat treatment, %

It has also been experimentally proved that all samples with a protective coating for the whole period of storage had a slight loss in their mass moisture content. They had lower drying loss and, thus, a higher yield after heat treatment, which makes it possible to obtain additional profit. In sample 1, for 7 days, the losses increased by an average of 8 %, while in samples 3 and 4 losses, on the contrary, decreased by about 6%.

Conclusion

The following effective composition of the poly-component edible film-forming coating for natural semi-finished pork meat products has been suggested: agar – 0.25%, citric pectin – 0.5%, citric acid – 0.5%, parsley CO_2-extract or ginger CO_2-extract – 0.1%. The optimum shelf life of natural semi-finished pork meat products with an edible film-forming coating developed is 7 days at a temperature (–1…+1)°C, which is 2 days longer compared to the best-before date provided for in the regulatory document DSTU4590: 2006.

The developed edible compositions of film-forming coatings are an effective means of antioxidant protection of natural meat semi-finished products and prolong the shelf life of products. These coatings have barrier properties to ensure the quality and safety of meat products.

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