Improvement of meat storage technology as a factor in increasing the efficiency of the development of the agro-industrial complex

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Abstract. The formula for a membrane solution with antioxidant and antimicrobial spectrum has been developed. 4% of agar agar, and 2% of glycerol were used as the main ingredients of the membrane solution, 1% of food additive arabinogalactan (E 409) was used as an antioxidant, and 0.02% of antibiotic nisin was used as an antimicrobial agent. These ingredients were diluted with distilled water to 100%. Addition to the basic formula of the membrane arabinogalactan makes it possible to increase strength and elongation. The biodegradability of the membrane when placed in a 0.5% solution of hydrochloric acid, containing all the enzymes of gastric juice was 25.4 minutes. It was found that samples of chilled meat packed in the developed membrane after 10 days of refrigerated storage corresponded to fresh organoleptic, physicochemical and microbiological indicators. Acid and peroxide numbers of fat samples were within normal limits. As a result, it was revealed that the packaging of chilled meat in the developed membranes helps prevent microbial and oxidative damage to the product, which allows positioning it for implementation in the agro-industrial complex.

1. Introduction
The meat industry is one of the socially significant sectors of the agro-industrial complex (AIC). Russia achieved food sovereignty on meat due to the intensification of pig and poultry farming, the further development of these industries is determined by the export-oriented strategy.

Of particular importance in these conditions is the improvement of technologies for the storage of meat and meat products. Along with traditional methods of preserving food products, new methods are being developed, in particular, ultra-pasteurization, high pressure processing, ionization, high-voltage arc discharge (HVAD), cold plasma (CP) and others.

[1,2] The authors found that the meat processing with a pressure of 600 MPa at 20°C for 180 seconds causes the death of infectious agents of listeriosis (Listeriamonocytogenes), Escherichia coli (E. coli), Salmonella, Vibrio cholera (Vibrio), most species of mold fungi and pathogenic bacteria. The spores of Clostridiumbotulinum and some representatives of the genera Bacillus and Clostridia can be destroyed due to the synergistic effect of temperature and barometric factors.

It should be noted that the waste products of microorganisms (toxins) are likely to cause poisoning in humans who consume stale meat products. So Shiga toxin producing Escherichia coli O157: H7 (STEC) is a common contaminant in meat. Studies conducted [3] proved that the use of high-pressure...
processing of minced chicken meat destroys Escherichia coli and STEC. At the same time, an important factor in the inactivation of STEC, in addition to pressure (250–350 MPa), is temperature (-15–4°C) and exposure under pressure (10–20 min).

The quality of meat after processing it with pressure was investigated [4], and found out that under the pressure of 130-520 MPa for 4.3 minutes there is a stunning growth of microorganisms in meat for a week.

However, as stated in the study [5], high-pressure processing of food products can lead to morphological and genetic changes of microbial cells against the background of adaptation to the environment (modified conditions - high-pressure processing). Thus, ultrahigh pressure inhibits DNA replication enzymes and gene expression of microorganisms, which leads to activation of regulatory genes and, ultimately, to the formation of stress-resistant strains.

Studies have shown that a pressure of more than 800 MPa leads to increased oxidative processes in meat [6].

A promising way of preserving meat is its processing with ionization. In 2017 the Russian Federation introduced the State All-Union Standard (GOST) 33820-2016 “Fresh meat and frozen. Irradiation guidelines for the destruction of parasites, pathogens and other microorganisms” and the GOST 33825-2016 "Packed semi-finished meat products. Irradiation guidelines for the destruction of parasites, pathogens and other microorganisms" [7]. One of the main advantages of radiation processing is its high penetrating ability, which enables to process the products in packaging, preventing re-contamination of the product. But at the same time, ionization leads to the formation of free radicals in the product and, accordingly, increased oxidative damage.

The HVAD technology is based on creating a high-pressure shock wave by the arc discharge, which causes cavitation, and cavitation bubbles, in turn, create strong secondary impacts. The shock wave concerns the cell membranes, which causes their mechanical rupture and the release of cell contents. But at the same time, the voltage of the arc discharge contributes to the formation of highly reactive free radicals and, accordingly, can lead to increased oxidative processes [8, 9].

The use of low-temperature plasma to preserve food is an innovation in the processing industry. Plasma is essentially the fourth state of matter aggregation (besides liquid, solid and gas). From the perspective of physical chemistry, plasma is an ionized gas. Cold plasma is a plasma containing neutral particles (atoms and molecules) and particles carrying a charge (electrons, cations and anions), products of plasmochemical reactions (free radicals) [10, 11].

The technology of using cold plasma is understudied, which makes it impossible to fully evaluate all the risks of its use [12]. To date, it is known that cold plasma has been used in the food industry to disinfect agricultural products (apples, lettuce, almonds, mangoes and melons), the surface of eggs, meat, cheese [13].

Based on the above, it is necessary to develop new technologies for the storage of meat and meat products, which have an antimicrobial effect, but also prevent the oxidative processes occurring during storage.

One of the promising areas in this area is the creation of edible biodegradable membranes with high antimicrobial and antioxidant activity.

As the main ingredient of the formula for edible biodegradable membranes, hydrocolloids, in particular, alginate, agar, carrageenan, carboxymethylcellulose, pectin, xanthan gum, chitosan, starch and others are used [14, 15]. To obtain membranes, it is important that plasticizers are present in the formula — glycerin, propylene glycol, sorbitol, sucrose, polyethylene glycol, water, etc. Also, emulsifiers are sometimes added — lecithin, tweens, spans, lipid emulsions, and fatty acids are most often used. Sometimes for membranes production it is necessary to add crosslinking agents to achieve the best strength and thermal stability [16].

For the production of edible membranes, a spunbond (continuous "dry") and discontinuous ("wet") and extrusion methods are used.

The objective of the work is to develop an antimicrobial and antioxidant biodegradable edible membrane and to evaluate its effectiveness on the example of the keeping quality of refrigerated meat.
2. Material and research methods

The quality of the membrane was evaluated by organoleptic (consistence, color, taste and smell) and physical-chemical (solubility), as well as structural-mechanical (thickness, strength, elongation under tension) properties.

The thickness and density of the membranes were identified using a micrometer MK 50-1, solubility was calculated by the formula, biodegradability - by placing the film in an equivalent of gastric juice and determining the disintegration time, strength and elongation using a test set.

Evaluation of the quality of meat packaged in the developed membrane was carried out according to organoleptic, physical-chemical and microbiological parameters in accordance with generally accepted methods.

Samples of refrigerated meat of the first (control) group were placed in a membrane from the base membrane solution consisting of agar-agar, food glycerin and distilled water; meat samples of the second (experimental) group were packed into a membrane from the base solution, antibiotic nisin and antioxidant substances - arabinogalactan. All samples of meat researched were stored at a temperature ranging from 0 to 2°C.

3. Research results

The formula for a membrane solution with antioxidant and antimicrobial spectrum has been developed. 4% of agar agar, and 2% of glycerol were used as the main ingredients of the membrane solution, 1% of food additive arabinogalactan (E 409) was used as an antioxidant, and 0.02% of antibiotic nisin was used as an antimicrobial agent. These ingredients were diluted with distilled water to 100%. The membrane was made by warm extrusion. The obtained control and test samples of the membrane were uniform in thickness, transparent and elastic, had no taste and smell. Therefore, the addition of arabinogalactan and nisin to the membrane solution did not adversely affect the organoleptic properties. These characteristics make it possible to use the membrane for packaging meat for processing. The thickness of the control and test membrane samples had no significant differences and amounted to 48.3 and 48.9 µm. It should be noted that the strength and elongation at fracture in the test samples were at the level of 34.5 MPa and 31.7%, while in the control samples - 32.1 MPa and 28.5%, respectively.

Improvement of the structural and mechanical properties of the membrane prototypes is associated with the gel-forming ability of arabinogalactan. The biodegradability of the control and test samples when placed in a 0.5% solution of hydrochloric acid, containing all the enzymes of gastric juice, was 25.4 min. After 10 days, assessment of the quality of refrigerated meat packed in control and test membranes samples was carried out (table 1).

| Table 1. Organoleptic properties of control and test meat samples after 10 days of cold storage. |
|---------------------------------|----------------|----------------|
| Indicator name                  | Group 1 (control) | Group 2 (test) |
| Appearance and color            | Highly moist, sticky; color: maroon | Partly slightly moist; color: pink |
| Muscle tissue on the cut         | The muscles are wet, sticky, dark red in color, leaving a damp spot on the filter paper | The muscles are slightly wet, do not leave wet spots on the filter paper |
| Consistence                     | On the cut less dense and less elastic; the depression formed when pressing with a finger is practically leveled | Elastic, dense, the deepening which is formed when pressing a finger is leveled quickly |
Table 1 indicates that the samples of the first group after 10 days of storage on organoleptic indicators had signs of meat of questionable freshness, while the samples of the test group were fresh.

The indicators of oxidative spoilage of meat during storage (acid and peroxide values of fat isolated from meat) were studied. It was found out that after 10 days of storage, the acid and peroxide numbers of the fat samples were within the normal range and were at the level of 0.9 mgKOH/g of fat and 1.8 mmol of active oxygen/kg of fat, in the control samples - 3.6 mgKOH/g of fat and 6.9 mmol of active oxygen/kg of fat, respectively. The data obtained indicate the antioxidant activity of test membrane samples.

Table 2 presents the microbiological indicators of the meat samples after 10 days of cold storage.

**Table 2. Microbiological indicators of control and test meat samples after 10 days of cold storage.**

| Indicator name | Group 1 (control) | Group 2 (test) |
|----------------|-------------------|----------------|
| QMAFAnM, UFC/g | 3,40 x10⁴         | 1x10           |
| Coliforms (g), are not allowed in 0.1g of products | -                | -              |
| Yeast, UFC/g   | 1,2x10⁵           | 1,3x10         |

Table 2 indicates that the QMAFAnM in the meat samples of the control group is 3.4×10³UFC/g at a rate of not more than 1.0×10⁴UFC/g. The number of yeast cells in the control samples was 1.2x10⁵UFC/g at a rate of not more than 1x10⁶UFC/g. While in experimental samples of QMAFAnM and yeast are significantly lower than 1x10⁶ and 1.3x10⁶ UFC/g, respectively.

**4. Conclusions**

Based on the conducted research, biodegradable antimicrobial and antioxidant membranes with high organoleptic characteristics and structural-mechanical properties, including agar-agar, glycerin, arabinogalactan and nisin, have been developed. Packing refrigerated meat in developed membranes helps prevent microbial and oxidative damage to the product.

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