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Use of Arabinogalactan for Storage of Chilled Fish

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***Abstract*—The use of modern technologies for storing chilled raw fish allows us to regulate the logistic delivery system from the fishing location without freezing or temporary freezing with maintaining the state of aggregation of fresh and chilled fish to the consumer market of the inland territories of the Russian Federation. One of the promising ways to extend the shelf life of chilled fish is the use of food additives, in particular the arabinogalactan, in the preparation of small flake ice made from electrolysed water. Arabinogalactan, which has bactericidal properties, contributes to the preservation of chilled fish, which is confirmed by organoleptic characteristics, and due to diffusion it enriches the surface layers of fish with soluble dietary fiber. According to the results of experimental studies, it was found that the storage of chilled fish in a cooling medium of small flake ice prepared from a 1-3% electrolysed aqueous solution of arabinogalactan provides high microbiological safety throughout the entire storage period and prolongs storage periods up to 45 days by reducing the rate of hydrolytic and oxidative processes.**

Keywords—fish, arabinogalactan, small flake ice, electrolysed water, microbiological indicators, freshness indicators.

I. INTRODUCTION

In order to achieve food independence and increase the competitiveness of domestic products in foreign world markets, and according to the Decree of the President of the Russian Federation dated 01.12.2016. "On the strategy of scientific and technological development of the Russian Federation", priority areas must be the ones that contribute to the emergence of innovative technologies that ensure the preservation and efficient processing of food products [1]. Fish is a valuable source of digestible protein and unsaturated fatty acids (oleic, linoleic, linolenic, arachidonic) necessary in human nutrition, which make up 85% of the total amount of fats needed in human nutrition. The biological value of fat is determined by derivatives of linoleic and linolenic acids and fat soluble vitamins A, D and E. Due to the high content of unsaturated fatty acids under environmental impact (air, water, light, temperature), raw fish is notable for its storage instability, due to the hydrolytic and oxidative processes, which affects the shelf life. Unprocessed fish requires special storage conditions throughout the shelf life to ensure fish safety in accordance with the requirements of the technical regulation of the Eurasian Economic Union "On the safety of fish and fish products" (EAEU TR 040/2016).

II. LITERATURE REVIEW

The principle of preservation of food raw materials is based on partial or complete suppression of the biochemical processes occurring in it (according to the classification of Prof. Ya.Ya. Nikitinsky) and is determined by thermo-anabiosis during freezing / cooling and drug-anabiosis during storage in gaseous media (nitrogen, carbon dioxide, oxygen, ozone) due to the slowdown of metabolic processes in cells and the suspension of the activity of microorganisms to more favorable conditions for their existence, as well as chem-abiosis as an additional method.

To preserve food resources, preserving factors for food are used, conventionally divided into physical, chemical and biological factors. To store fish products in fresh, chilled and frozen in particular, as the most traditional form, physical factors are actively used due to the effect of low temperatures when cooled by a stream of air on raw fish of any shape and size, unpacked and packaged. The speed of freezing / cooling is determined by temperature conditions, air circulation and product size. Due to the fact that the cooling air flow is directed from one side, not the entire surface of the product is involved in heat transfer, which leads to uneven cooling. Moreover, air is characterized by a relatively low ability to accumulate heat and is prone to moisture absorption [2-9].

In accordance with the requirements of the Technical Regulation of the Eurasian Economic Union "On safety of fish and fish products", chilled fish includes fish subjected to a cooling process without reaching the freezing temperature of tissue liquid, as well as fish products subjected to a cooling process to a temperature in the thickness of the product not higher than +5 °C. Chilled fish according to GOST 814-96 "Chilled fish. Technical conditions" can be stored in ice for up to 7-12 days, depending on the size of the fish and the period of fishing (year quarter).

To increase the duration of storage of chilled fish up to 10 days, a method is applied in which carbon dioxide snow is applied to the surface of the fish [10] or to its internal cavity [11]. In this case, more intensive cooling of the inner or outer surface of the fish occurs, depending on the place of application of the carbon dioxide snow, and also there is a need for hermetic packaging of fish to preserve carbon dioxide during the entire period of storage of the fish. When applying this method, it must be borne in mind that in terms of the degree of exposure to the human body, carbon dioxide belongs to the 4th hazard class. Carbon dioxide itself is non-toxic, but when exposed to elevated concentrations, it is possible to suffocate a person, which can lead to the development of drowsiness and weakness. When carbon dioxide snow enters the skin of a person, it causes severe frostbite.

In recent years, to extend the shelf life of chilled fish products in demand on the consumer market, the use of following preservative additives is proposed: salt, sugar, acids, alcohol, preservatives, stabilizers, antioxidants, antibiotics, food additives, etc.

The use of storage methods is determined primarily by the current system of healthy nutrition of the population of our country due to a balanced and safe diet, which contributes to the normal development and functioning of the human body [12].

The use of ice as a cooling reagent with the addition of various types of food additives, the so-called prebiotics, due to the combined action of physical and chemical factors, leads to an extension of the shelf life of chilled fish [13-14].

Prebiotics, not absorbed in the small intestine, form a favorable environment for the growth of microbiota of the large intestine. The most famous prebiotics include dietary fiber; pectin; oligo- and polysaccharides; dextrin; chitosan; amino acids – valine, arginine, glutamic acid; ubiquinone; carotenoids; vitamins A, E and C, etc.

The antioxidants inhibit the self-oxidation of raw fish materials, which is a source of valuable fusible, but unstable during storage of fat. Antioxidants can stop chain reactions, thereby increasing the oxidative stability of foods.

By treating the surface of fresh fish with powdered sucrose, shelf life is extended to 3 months at a storage temperature of +2…+6 °C [15].

In recent years, the use of food additives has been widespread, which allows to extend shelf life, for example, when using as a cooling medium a 2-3% aqueous solution of the "Frische -Star" food additive for gutted fish for 15-25 minutes at a temperature from 0 to minus 3 °C and subsequent storage of fish in ice. During the first 7 days, the fish is stored in fresh ice with the replacement of melted ice. Then, on the 8-10th day of storage, the fish is poured with ice obtained from a 0.1-0.2% aqueous solution of citric acid [13]. However, it should be borne in mind that the composition of the "Frische -Star" food supplement includes: food supplement E 262 (sodium acetate), which is contraindicated for people suffering from vegetative-vascular dystonia, arterial hypertension, dysbiosis, as well as diseases of the urinary tract, intestines, gall bladder, liver; and food supplement E 330 (citric acid), which damages teeth enamel and irritates the stomach mucosa when overused.

To extend the shelf life, it is proposed to store chilled fish in flake ice prepared from a 1% solution of food supplement "Varex-7" and a 3% aqueous solution of sodium chloride. Fish is stored in a refrigerator at a temperature of -1 °C to -3 °C with a ratio of fish mass to ice mass of 2: 1 [14]. However, when "Varex-7" and table salt are added to flake ice, the ice thaws upon contact with fish, which requires its replacement. With a long shelf life (up to 28 days) in the surface layers of the fish muscle tissue, an excessive amount of the food supplement "Varex-7" is adsorbed, which includes sorbic acid (E 200), which has a destructive effect on vitamin B12 and, in certain cases, leads to allergic reactions in humans. The permissible dosage of E 200 should not exceed the level of 25 mg/kg of a healthy adult. Accordingly, constant monitoring of the residual content of food additive E 200 in chilled fish is required – not more than 0.15%.

Discovered that the shelf life of chilled fish increases to 37 days when stored at a temperature of from -1 °C to -3 °C in flake ice made from electrolysed water with bactericidal properties and a pH of 5.2-5.5 units [16].

One of the promising food additives to extend the shelf life is arabinogalactan (E 409), obtained from acacia gum and larch. This is a water-soluble polysaccharide with a high molecular mass, the macromolecules of which have a branched structure: galactopyranosyl links are connected by β- (1→3) bonds, galactopyranosyl and arabinofuranosyl links are connected by β- (1→6) bonds [17].

Arabinogalactan is a light cream-colored finely divided powder with a sweet taste, which is highly soluble in water, resistant to high temperatures and acidity of the environment, and is used in the food industry as a thickener, gelling agent and stabilizer [18-19], for binding fat and moisture retention [20].

Arabinogalactan has the ability to prevent lipid oxidation, regulate moisture-binding ability, bind free radicals, some pharmacological properties: hepatoprotective, immunostimulating and membranotropic effects and increases the permeability of blood vessels [21-24].

Arabinogalactan possesses the properties of prebiotics [25-27] and, as a source of soluble dietary fiber and fiber, affects the process of digestion of food in the gastrointestinal tract (GIT).

From a clinical point of view, arabinogalactan helps maintain immunity by creating favorable conditions for the development of beneficial Lactobacilli and Bifidobacteria and maintaining the balance of microbiota, as it is a fermentable fiber [28].

The use of arabinogalactan in the food industry is regulated by the requirements of SanPin (Sanitary Regulations and Standards) 2.3.2.1078-01 "Hygienic requirements for food safety and nutritional value"; SanPiN 2.3.2.1293-03 "Hygienic requirements for the use of food additives" and Methodological recommendations No. 2.3.1.1915-04 "Recommended levels of consumption of food and biologically active substances", which establish an adequate and upper acceptable level of consumption of arabinogalactan – 10 and 20 g per day, respectively.

According to [29], arabinogalactan, as a promising synthon, reacting with mono- and bifunctional reagents forms new water-soluble preparations whose properties are determined by the properties of arabinogalactan itself and introduced functional groups.

The use of arabinogalactan provides a high content of dietary fiber with little effect on the palatability of food products [30]. Arabinogalactan improves the organoleptic properties of flour confectionery and bread and enriches feremneted milk products, fat-and-oil and juice products with dietary fiber.

In addition, arabinogalactan, having dispersing and deflocculating properties, is used as an emulsifier to stabilize emulsions [31].

In this regard, these studies have been conducted on the effect of arabinogalactan, as a food supplement, on the shelf life of chilled raw fish.

III. Research methodology

The objective is to study the possibility of extending the shelf life of chilled fish in small flake ice prepared on a 1-3% aqueous electrolysed solution of arabinogalactan.

Research objects include chilled fish (common carp of a pond fish farm) weighing 500-600 g according to the

requirements of GOST 1368-2003 "Fish. Length and weight" of 10 pcs. in each group. Following groups were formed:

- the 1st group of fish is stored in small flake ice made from electrolysed water with a pH of 5.2;
- the 2nd group of fish – in small flake ice from a 1% electrolysed aqueous solution of arabinogalactan with a pH of 5.2;
- the 3rd group of fish – in small flake ice from electrolysed water with a pH of 5.5;
- the 4th group of fish – in small flake ice from a 1% electrolysed aqueous solution of arabinogalactan with a pH of 5.5.

Small flake ice is used as a cooling medium, which was prepared from a solution of electrolysed water with a pH of 5.2-5.5 units, obtained by electrolysis of tap water in a STEL-10N-120-01 unit at a current strength of 3.5 A, with the addition of arabinogalactan powder at the rate of 1-3 g per 100 ml of water; a 1-3% electrolysed aqueous solution of arabinogalactan is obtained.

Such a dose of arabinogalactan is safe for humans and does not exceed an adequate and upper allowable level of consumption of arabinogalactan according to Methodological Recommendations 2.3.1.1915-04 "Rational nutrition. Recommended levels of intake of food and biologically active substances".

The use of arabinogalactan in the production of a cooling medium is explained by the fact that arabinogalactan is a safe plant polysaccharide that is highly soluble in water, highly stable at various pH conditions and exhibits antioxidant (prevents lipid peroxidation) and bactericidal (prevents microbiological spoilage) properties [19], [32-33].

IV. Experimental study

When tested, the organoleptic characteristics of chilled carp samples of all groups met the requirements of GOST 814-96 "Chilled fish. Technical conditions". The surface of the carp is clean, the mucus is light, the gills are reddish-brown, the texture is elastic, the smell is characteristic of fresh fish.

Freshness indicators of chilled fish were evaluated over the entire storage period after 5; 28; 37 and 45 days according to Methodological Regulations 4.2.1847-04 "Methods of control. Biological microbiological factors. Sanitary and epidemiological assessment of the justification of the shelf life and storage conditions of food products. Guidelines".

It was found that organoleptic and microbiological indicators in all 4 groups when stored for up to 37 days correspond to an acceptable level according to the requirements of GOST 814-96 "Chilled fish. Specifications" and Technical regulations of the Eurasian Economic Union 040/2016 "On the safety of fish and fish products" and according to QMAFAnM (Quantity of Mesophilic Aerobic and Facultative Anaerobic Microorganisms), no bacteria of the Escherichia coli group, Staphylococus aureus, Vibrio parahaemoliticus were found.

After 45 days, in the samples of fish of groups 1 and 3, there is a clouding of the surface of the carp, the color of the gills is brown, the texture of the muscle tissue is soft and there is a smell of oxidative damage, in samples of groups 2 and 4 the organoleptic characteristics comply with the requirements of GOST 814-96.

When stored for up to 45 days in small flake ice from electrolysed water with pH values of 5.2 and 5.5 (fish samples of the 1st and 3rd groups), QMAFAnM exceeds the permissible level by 4.1 and 6.1 times and is $4.1 \cdot 10^5$ and $6.1 \cdot 10^5$ CFU/g, respectively. When stored in small flake ice from a 1% electrolysed aqueous solution of arabinogalactan with a pH of 5.2 (fish samples of the 2nd group), the QMAFAnM indicator corresponds to the permissible level and is equal to $3.5 \cdot 10^3$ CFU/g, when stored in small flake ice from 3% electrolysed aqueous solution of arabinogalactan with a pH of 5.5 (samples of fish of the 4th group) QMAFAnM indicator is $4.5 \cdot 10^3$ CFU/g (Tab. I).

TABLE I. Microbiological indicators of samples of chilled fish during storage (n=10)

Group	Indicators			
	QMAFAnM, standard - not more than $1 \cdot 10^5$ CFU/g	***Coliform bacteria, not acceptable in 0.001 g of product weight***	***S. aureus, not acceptable in 0.01 g of product weight***	***V. parahaemoliticus, standard - not more than 100 CFU/g***
After 5 days of storage				
1 group	$1.3 \cdot 10$	Absence	Absence	Absence
2 group	$1.2 \cdot 10$	Absence	Absence	Absence
3 group	$1.3 \cdot 10$	Absence	Absence	Absence
4 group	$1.2 \cdot 10$	Absence	Absence	Absence
After 28 days of storage				
1 group	$1.5 \cdot 10$	Absence	Absence	Absence
2 group	$1.3 \cdot 10$	Absence	Absence	Absence
3 group	$1.7 \cdot 10$	Absence	Absence	Absence
4 group	$1.3 \cdot 10$	Absence	Absence	Absence
After 37 days of storage				
1 group	$2.3 \cdot 10^2$	Absence	Absence	Absence
2 group	$1.9 \cdot 10^2$	Absence	Absence	Absence
3 group	$2.8 \cdot 10^2$	Absence	Absence	Absence
4 group	$2.1 \cdot 10^2$	Absence	Absence	Absence
After 45 days of storage				
1 group	$4.1 \cdot 10^5$	Absence	Absence	Absence
2 group	$3.5 \cdot 10^3$	Absence	Absence	Absence
3 group	$6.1 \cdot 10^5$	Absence	Absence	Absence
4 group	$4.5 \cdot 10^3$	Absence	Absence	Absence

It was experimentally established that the freshness indicators (acid number, peroxide number) in all 4 groups when stored for up to 37 days correspond to the permissible level (Fig. 1, 2).

When stored up to 45 days in small flake ice from electrolysed water with pH 5.2 and 5.5 (fish samples of the 1st and 3rd group), the acid value exceeds the permissible level and is 4.1 and 4.3 mg KOH/g, respectively. When stored in small flake ice from a 1% electrolysed aqueous solution of arabinogalactan at pH 5.2 (fish samples of the 2nd group), the acid value corresponds to the permissible level and is equal to 1.7 mg KOH/g, when stored in small flake ice from 3% a second electrolysed aqueous solution of arabinogalactan with a pH of 5.5 (samples of fish of the 4th group) – 2.1 mg KOH/g, respectively (Fig. 1).

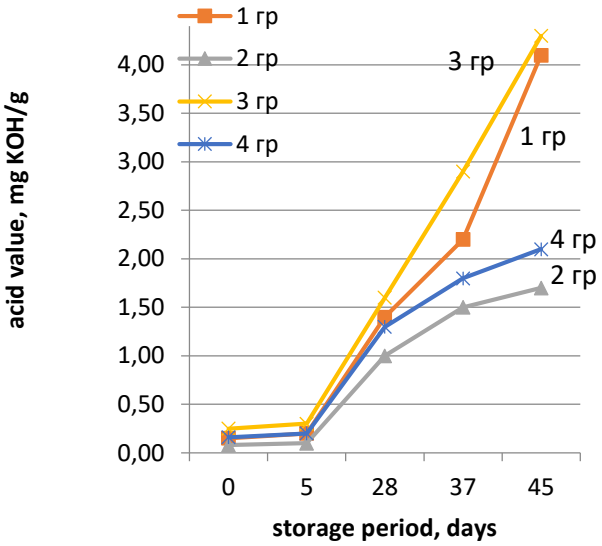

Fig. 1. Acid value of chilled fish during storage in small flake ice from electrolysed water, mg KOH/g

When stored for up to 45 days in small flake ice from electrolysed water with a pH of 5.2 and 5.5 (fish samples of the 1st and 3rd group), the peroxide value exceeds the permissible level and is 10.2 and 11.3 mmol of active O_2/kg, respectively. When stored in small flake ice from a 1% electrolysed aqueous solution of arabinogalactan with a pH of 5.2 (fish samples of the 2nd group), the peroxide value corresponds to an acceptable level of 4.1 mmol of active O_2/kg; when stored in small flake ice from 3% a second electrolysed aqueous solution of arabinogalactan with a pH of 5.5 (samples of fish of the 4th group) – 4.5 mmol of O_2/kg, respectively (Fig. 2).

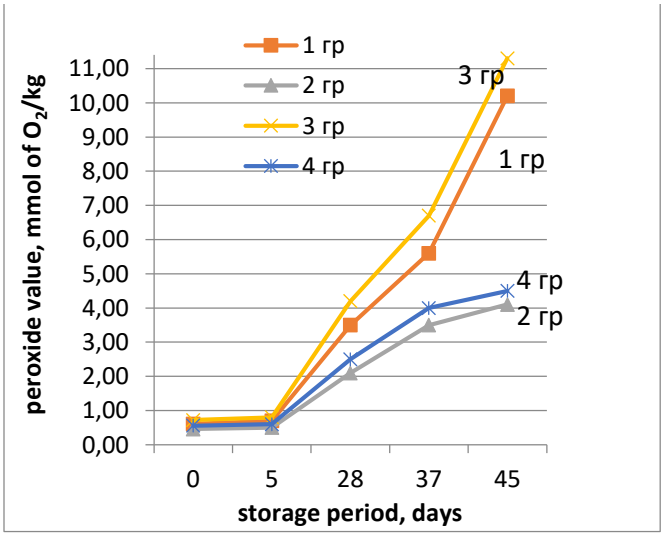

Fig. 2. Peroxide value of chilled fish during storage in small flake ice from electrolysed water, mmol of active O_2/kg

V. Results

Arabinogalactan use for the preparation of a solution of electrolysed water and its subsequent use for the preparation of small flank ice allows extending the shelf life of chilled fish when storing fish in small flake ice at a temperature of from -1 °C to -3 °C for up to 45 days. This ensures the preservation of the quality of chilled fish by preventing oxidative and microbiological damage to the product and improving organoleptic properties by densifying the surface of the skin, delaying the evaporation of moisture and preserving the juiciness of the fish pulp. The established fact of prebiotic properties in fish due to enrichment with soluble dietary fiber is also important.

VI. Practical Significance

Application of the proposed method allows to increase the shelf life of chilled fish in small flake ice up to 45 days. Extending the shelf life of chilled fish will make it possible to supply high-quality chilled fish from fishing areas to the internal territorial entities of the Russian Federation, expanding the range of fish in the consumer market, and will strengthen economic ties between the regions of the country. The effectiveness of the proposed storage method according to the results of experimental studies will be determined by reducing the loss of valuable raw fish food materials during transportation and storage.

VII. Conclusion

As a result of the studies, it was established that the use of 1-3% electrolysed aqueous solution of arabinogalactan with a pH of 5.2-5.5 units in the production of small flake ice, used as a cooling medium, ensured safety throughout the entire storage period due to the antioxidant and bactericidal properties of the cooling reagent and allowed to increase the shelf life of chilled fish by 1.6 times compared to the storage method without arabinogalactan [16]. Indicators of microbiological safety and freshness are within normal limits for storage up to 45 days. Preservation of high biological value of chilled fish due to a decrease in the rate of lipid oxidation processes has been established; improvement of organoleptic properties due to compaction of the skin surface, retardation of moisture evaporation and preservation of juiciness of fish pulp and the appearance of prebiotic properties in fish due to enrichment with soluble dietary fiber.

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