The substantiation of technological regimes of production of refrigerated semi-finished products from Japanese mackerel with prolonged storage time

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Abstract. One of the actual areas of processing the aquatic biological resources is the production of chilled fish semi-finished products that are most prepared for heat treatment. The goal of this research was to substantiate the technological regimes for the production of chilled mackerel fish semi-finished products with extended shelf life. It was experimentally found that the treatment of mackerel with developed salting media, including moisture-retaining components, organic acids and flavoring additives with anti-bactericidal properties, improves the organoleptic characteristics of the finished product, contributes to faster maturation, salt penetration into the fish, and a decrease in the total number of microorganisms (QMAFAnM). The increase in amine nitrogen ranged from 1.4 g/kg (at the beginning of the salting) to 1.55 g/kg in the control and up to 3.05 g/kg in the test samples by the end of the salting. Salt concentration in mackerel treated with control medium for salting amounted to 1.19%, new developed media - from 2.84 to 3.17%. The total amount of microorganisms in mackerel is $2 \times 10^2$ CFU/g. After salting it decreased and varied from 0.1 to $3.0 \times 10^1$ CFU/g. According to the research results, the rational duration of the salting of mackerel, treated with new media for salting within 4 - 5 hours at a temperature of 6 - 8°C, has been determined. The use of Darfresh film for packaging, which provides an additional barrier to oxygen and water vapor, increases the shelf life of the finished product.

1. Introduction

At present, one of the actual areas of processing of aquatic biological resources is the production of refrigerated semi-finished products from cut fish on a carcass, piece or fillet as much as possible prepared for heat treatment. The need for this type of product is associated with the trends of healthy eating of the population, with the growing pace of life and limited time for cooking. Such products are currently represented in the Russian market mainly by semi-finished products from meat raw materials, which are in high demand among the population. Similar products from fish are produced only in certain regions and its range is very limited [1].

One of the important technological operations in the production of fish semi-finished products can be a short-term raw meal salting, which ensures the penetration, distribution, and accumulation of salting components in fish; change in the state of protein substances; changes in the forms of the moisture bonds, the moisture-binding capacity and the mass of the fish; development of chemical and
enzymatic processes with the formation of flavoring substances; change in the quantitative content and qualitative composition of microorganisms [2,3,4]. Short-term fish salting is considered not only as a method of preserving the raw fish materials and finished products, but also as one of the methods of technological processing, which allows one to modify the properties of the main raw materials for subsequent production of various types of products from it by using different types of heat treatment. Modern technologies use the introduction of brines into raw fish materials by injection (syringing) followed by mechanical processing of raw materials, or by keeping the fish in the brine or outside it. In this case, the salting process has a diffusion-osmotic nature, and its acceleration is achieved by using a combination of different physical and chemical methods.

When salting the fish, salting substances and food additives are used, both for surface treatment of raw fish materials, and for preparing brines, marinades, and other types of multicomponent solutions of various technological purposes on their basis [5].

The most promising are multicomponent brines containing soy protein isolates, carrageenans, and native starches in addition to salting and phosphate. The prevailing preferential attitude towards these high-molecular substances is primarily due to their guaranteed biological safety, relative simplicity of technological use, high functional and technological properties, market and economic accessibility.

Therefore, the process of selecting the types and quantities of ingredients for brine systems is a critical issue that can significantly affect the organoleptic, physical and chemical, structural and mechanical characteristics, as well as the shelf life and yield of the finished product.

Taking into account the consumer's orientation towards natural healthy food, the demand for chilled semi-finished fish as much as possible prepared for heat treatment from environmentally friendly raw materials with the addition of spices, kitchen herbs, and various marinades will continue to increase substantially [6,7,8]. Therefore, there is a need to search for technological methods, with which you can increase the shelf life of such products.

2. The purpose of the study
An important task is to obtain chilled fish semi-finished products with high organoleptic characteristics and prolonged storage periods. Japanese mackerel is used as a raw material for semi-finished products. Natural functional food additives are used as part of brine systems. Packaging of products is carried out in a barrier film Darfresh. The goal of this research was to substantiate the technological regimes for the production of chilled fish semi-finished products from mackerel, which provide extended shelf life of the finished product.

3. The object of the study
The object of the study was chilled semi-finished products obtained from Japanese mackerel (Scomber japonicus) caught in the Sea of Japan.

4. Materials and methods
For the experimental study we used frozen Japanese mackerel (Scomber japonicus), which was bought in the fishing port of Vladivostok (Russian Federation) at the Sigma Marine Technology Ltd. Auxiliary materials were used for technological purposes: grade salt, granulated sugar, ascorbic acid, mustard powder, carrageenan, dried rosemary, soy isolate, citric acid, coriander, lemongrass, black pepper ground, garlic, ground red pepper, thyme, lemon balm, a mixture of bell peppers, and ground cardamom. Auxiliary materials were purchased in the trade network of Vladivostok, Russian Federation. Their quality meets the requirements of technical regulations of the Russian Federation.

In the production of semi-finished products, mackerel was preliminary salted in the curing media according to recipes 1, 2, 3. The control was a curing mixture consisting of water, salt, and sugar.

Composition of curing media:
control: water (83%) - salt (14%) - sugar - (3%);
recipe 1: water (83%) - salt (14%) - sugar - (3%) - trisodium pyrophosphate - (1%) – ascorbic acid - (0.5%) - mustard (0.1%);
recipe 2: water (83%) - salt (14%) - sugar- (3%) - carrageenan - (1%) - tartaric acid - (0.5%) - rosemary - (0.2%);
recipe 3: water (83%) - salt (14%) - sugar - (3%) - soy protein - (4%) - citric acid - (0.5%) - coriander - (0.2%).

When developing the formulations of multicomponent brines, we were guided by functional and technological properties, food additives used and recommended standards for their use in brines.

The mackerel was cut into fillets. The introduction of brines into the raw material was injected into the muscle tissue with the help of nickel-plated hollow perforated needles of 150-160 mm in the length, 1.5 mm in the inner diameter, and 3 mm in the outer diameter. The brine was injected into the raw material with a needle insertion pitch of 10 to 20 mm. The amount of brine introduced was 20% of the weight of the product. After syringing the fish with brine, it was kept at a temperature of 6 - 8 °C for five hours. The degree of salting was determined by the change in the concentration of sodium chloride in the raw material. The maturation of fish was estimated by the growth of amine nitrogen.

To determine the degree of salinization of the fish, an orgentometric method for the determination of table salt was used. The degree of hydrolysis of mackerel proteins during its aging in multicomponent brines was estimated by the accumulation of amino nitrogen, which was determined by the method of formal titration. The peroxide number of mackerel lipids was determined by the titrimetric method.

The Darfresh packaging film developed by the Swedish company Cryovas was purchased from LansPak, Moscow. Packaging of semifinished products was carried out by evacuation to Darfresh thermoforming films. Then the semi-finished products were cooled to the temperature in the center of the product of no higher than 3 °C and stored in a refrigerator at a temperature of 0-5 °C and an air humidity of 95-98% for 25 days.

The total number of the microorganisms (NMAAnM) in fish semi-finished products was determined by identifying the number of grown colonies of microorganisms on nutrient media from agar (Commission Regulation (EC), 2007).

5. Discussion of the results
The dependence of the change in the content of sodium chloride in mackerel on the duration of salting and the selected formulation is shown in figure 1.

![Figure 1](image.png)

**Figure 1.** Dependence of the change in the content of sodium chloride in mackerel on the duration of salting and the selected formulation

Study has shown that the salt concentration in the fish was 0.68% immediately after the introduction of brine into the muscular tissue of mackerel. It has been experimentally determined that mackerel injected with a multicomponent is salted faster than in control brine. Thus, after 1.5 hours, the salt concentration in the mackerel injected with control brine was 1.13%, and in the fish samples injected with multicomponent brines, the salt concentration ranged from 2.61 to 3.06%. The highest rate of salting out was measured in a sample of mackerel injected with a multicomponent brine prepared according to recipe No. 3, which included soy isolated protein and citric acid.
More intense degree of mackerel salting out in multicomponent brines is probably due to the breakdown of proteins and loosening of the structure of muscle fibers under the influence of phosphates, soy protein isolates, carrageenans, and organic acids.

With the subsequent aging of the mackerel samples in the salt for a further 3-5 hours, the degree of salting out of the brine formulation was directly related. After 5 hours of salting, the salt concentration in the mackerel injected with control brine was 1.19%, injected with multicomponent brines - from 2.84 to 3.17%.

It should be noted that, after injecting the mackerel with brine, swelling of the muscle tissue was noted, and throughout the salting time a separation of the injected brine did not occur, which again confirms that the muscular tissue of mackerel has a high water-binding capacity [9,10].

During mackerel aging after brine injection, the accumulation of amine nitrogen was monitored, according to the increment of which the degree of ripening of the fish was determined, depending on the duration of aging and the formulation of the salting mixture (Figure 2).

The results of the study showed that the speed and degree of ripening of mackerel directly depend on the formulation of saline brine. The amount of amine nitrogen immediately after injection was 0.7 g/kg of fish muscle tissue.

The greatest increase in amine nitrogen was measured in mackerel injected with multicomponent brine, prepared according to recipe No. 3, which included soy protein isolate, citric acid, and coriander. The increase in amine nitrogen was from 1.4 g/kg (at the beginning of the salting) to 3.05 g/kg by the end of the salting. The less intensive growth of amine nitrogen occurred in the control sample from 1.4 g/kg to 1.55 g/kg.

The effects of the components of the developed curing medium on changes occurring in the lipids of mackerel were investigated. It was experimentally determined that the peroxide number of lipids in fish before salting was 0.01% I₂; at the end of the salting process, the peroxide number in the control sample increased to 0.02% I₂; it remained at the same level in the newly developed salted media.

The injection of mackerel with multicomponent brines positively influences the organoleptic characteristics of raw materials. In the process of aging, the color of the fish improves, lightening of the muscular tissue of the mackerel from the dark beige with a brownish hue in the control sample to light cream after five hours of soaking takes place. In the process of salting the fish acquires a pleasant smell from brine compositions and spices. Consistency becomes more juicy and tender.

The conducted studies showed intensive growth of NMAFAnM in the first 1.5 hours of salting, followed by a decrease in the total number of microorganisms during aging was observed. More intensively, the microorganisms “died off” in samples injected with salting media. The total number of microorganisms in mackerel before salting was 2.0 x 10² CFU/g, after salting it decreased and did not exceed 3.0 x 10¹ CFU/g.
Therefore, along with technological methods of pretreatment of fish raw materials, there is a need to select packaging materials, with the help of which it is possible to extend the shelf-life of chilled fish products. A progressive method of packaging today is the use of protective barrier films, which are produced from various polymeric materials with different degrees of protection against external environmental factors [11, 12, 13]. Today, multilayer relief films of different manufacturers are available for in the food industry.

Compared to single-layer polyethylene films, the Darfresh packaging film, developed by the Swedish company Cryovac, is characterized by a more tight fit of the product (“second skin” effect) and additional barrier properties against oxygen and water vapor. Its use allowed one to extend the shelf life of vacuum packed chilled semi-finished mackerel products (Figure 3).

![Figure 3. Chilled semi-finished products from mackerel, packed in thermoformed film.](image)

According to the results of research the NMAFAnM on the 20th day of storage did not exceed the permissible levels and ranged from $6.9 \times 10^3$ to $9.0 \times 10^3$ CFU/g, depending on the recipes. Thus, the shelf life of culinary semi-finished products in Darfresh packaging was 20 days at a temperature of 0 - 5 °C and an air humidity of 95 - 98%.

The conducted study allowed to improve the technology for the production of chilled culinary semi-finished products from mackerel. The use of salted media developed by us in technology allowed to improve the organoleptic and microbiological parameters of the finished products, and to reduce oxidative processes. The application of Darfresh packaging film ensured the extension of the shelf life of chilled semi-finished products from mackerel to 20 days.

6. Conclusion

According to the results of the conducted studies, it is determined that the preliminary aging of the mackerel in salting positively influences the quality of the prepared semi-finished products. It has been experimentally found that injecting the mackerel with salting media improves the organoleptic parameters of the finished product. In the process of aging, the color of the fish improves, and the muscular tissue of the mackerel is lightened. In the process of salting the fish acquires a pleasant smell of brine compositions and spices. Consistency becomes more succulent, gentle, fibrous muscle tissue disappears. The taste becomes pleasant, depending on the formula with more or less pronounced sourness, with a hint of spices. The developed recipes compositions of salting media provide a faster glazing and ripening of the raw material comparing to the control sample. The conducted studies showed a decrease in the total number of microorganisms (QMAFAnM) in the process of aging in salting. Based on the results of the research, the rational duration of mackerel salting, injected with salting media, is 4-5 hours at a temperature of 6 – 8 °C. The use of Darfresh thermoforming film for packaging allows one to fix the fish in the package, to ensure the attractiveness of the goods for the consumer due to its transparency. The film has additional barrier properties to oxygen and water vapor. Its use allowed one to extend the shelf life of vacuum packed chilled culinary mackerel semi-finished products up to 20 days at a temperature of 0 - 5 °C and air humidity of 95 - 98%.
References

[1] Boland M J, Rae A N, Vereijken, JM, Meuwissen, M P M, Fischer A R H, Van Boekel M and Hendriks W H 2013 The future supply of animal-derived protein for human consumption *Trends in Food Science & Technology* **29** (1) 62-73 https://doi.org/10.1016/j.tifs.2012.07.002

[2] Kaya G K and Basturk O 2015 Determination of some qualitative properties of marinated sea bream (Sparus Aurata L., 1758) during cold storage *Sci Food. Radio Engineering (Campinas)* **35** (2) 347-353 https://doi.org/10.1590/1678-457x.6619

[3] Topuz O K 2016 Effects of Marinating Time, Acetic Acid and Salt Concentrations on the Quality of Little Tunny Fish (Euthynnus alleteratus) Fillet *Journal of Food Processing and Preservation* **40** (6) 1154-1163 https://doi.org/10.1111/jfpp.12696

[4] Ucak, Gokoglu 2016 The effect of high hydrostatic pressure on the sensory quality of a marinated herring (Clupeaharengus) *Journal of food industry and conservation* **41** (2) 12784 https://doi.org/10.1111/jfpp.12784

[5] Schuldt S, Raak N and Jaros D 2014 Harald Rohm Acid-induced formation of soy protein gels in the presence of NaCl *LWT - Food Science and Technology* **57** (2) 634-639 https://doi.org/10.1016/j.lwt.2014.02.013

[6] Pieniank Z, Verbeke W and Scholderer J 2010 Health-related beliefs and consumer knowledge as determinants of fish consumption. *Journal of Human Nutrition and Dietetics* **23** 480–488 https://doi.org/10.1111/j.1365-277x.2010.01045.x

[7] Zhang Y, Chen J, Qiu J, Li Y, Wang J and Jiao J 2016 Intakes of fish and polyunsaturated fatty acids and mild-to-severe cognitive impairment risks: a dose response meta-analysis of 21 cohort studies. *Am J Clin Nutr* **103** (2) 330-340 https://doi.org/10.3945/ajcn.115.124081

[8] Morales L E and Higuchi A 2018 Is fish worth more than meat? – How consumers’ beliefs about health and nutrition affect their willingness to pay more for fish than meat *Food Quality and Preference* **65** 101–109 https://doi.org/10.1016/j.foodqual.2017.11.004

[9] Naresh K M and Nayak B B 2017 Bio-chemical composition, functional, and rheological properties of fresh meat from fish, squid, and shrimp: A comparative study *International Journal of Food Properties* **20** (1) 707 – 721 https://doi.org/10.1080/10942912.2017.1308955

[10] Seokjin Suh, Yeong Eun Kim, Dongjae Shin and Sanghoon K 2017 Effect of frozen-storage period on quality of American sirloin and mackerel (*Scomber japonicus*) *Food Science and Biotechnology* **26** (4) 1077–1084

[11] Chouliara E, Karatapanis A, Savvaidis I N and Kontominas M G 2007 Combined effect of oregano essential oil and modified atmosphere packaging on shelf-life extension of fresh chicken breast meat, stored at 4 °C *Food Microbiology* **24** 607-617 https://doi.org/10.1016/j.fm.2006.12.005

[12] Lyhs U, Lahtinen J, Schelvis-Smit R 2007 Microbiological quality of maatjes herring stored in air and under modified atmosphere at 4 and 10°C *Food microbiology* **24** 507-516

[13] Ranmeechai N, Photchanachai S 2017 Effect of modified atmosphere packaging on the quality of germinated parboiled brown rice *Food Science and Biotechnology* **26** (2) 303–310