Rheological Characteristics of Modified Paste from Salmon and Low Valued Breeds of Fishes

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Abstract. The article deals with issues related to the assessment of the rheological characteristics of modified pastes from salmon and low-valued fish breeds. The current trend of processing low-value fish raw materials is accompanied by a search for new technologies that have not been used before and develops in two directions: the development of methods for manufacturing traditional products based on low-value fish raw materials and the production of protein-containing products, such as protein isolates, hydrolysates, and food fish meal, protein mass, minced fish, etc. This is due to the fact that about a third of the total world catch of all caught hydrobionts is used to the production of feed products and fish flour. At the same time, a lot of the small-sized fish breeds used for these purposes, although of small size, are little different in terms of chemical composition and nutritional value from those traditionally used, such as salmon species. So that they can be considered as an additional valued fish raw materials reserve for the preparation of food. The most promising recognized is the production of fish mince and the creation on its basis of various types of molded and structured products. The particular importance is the use of small-sized non-fatty fish, the mince from which is modified by the inclusion of food waste from valuable species of fish obtained by cutting of them. This allows you to send additional reserves of valuable food raw materials to produce food instead of using it for production of feeding.

1. Introduction
In recent years there has got concept of positive or functional nutrition, formed in Japan in the early 80s, becoming increasingly popular all over the world.

The production of various types of culinary products from mince requirements of the complex and full use of raw materials, as the enterprises use waste or inedible body parts of the fish (entrails, leather, etc.) more rationally. Such a group of products as meatballs, minced fish is produced from many species of ones, mainly from small fish and fish of reduced nutritional value with adding of food waste from cutting fish and non-fisheries objects of catch. There is fish with mechanical damage, with cutting defects, non-standard in size and deformed pieces used as raw materials [1-3].

The various types of molded, structured and emulsified products are produced on basis of fish mince. The using of it depends on the quality of ones and requires good knowledge of its organoleptic, in particular, rheological properties. The fish mince is used as a raw material for cooking of various dishes in catering and at home. These are meatballs, pies, stuffing for pies etc. At present, finished
molded fish mince products can be produced both by State Standards and by a significant amount of "Specifications for Fish Cooking", operating in particular for products of the Far Eastern basin.

2. Objects and methods of researching
The authors of the article have developed formulations of experimental samples of fish pastes. The theoretical basis for this was the data given in the scientific and patent literature, as well as, the data of practical tests. As the main raw material for the experimental samples were selected:
- fresh-frozen pollock, the catch area – Sea of Okhotsk, the quality of the relevant regulatory requirements.
- minced fish (MF), obtained from low-value and conditionally edible parts of Norwegian salmon, the catch area – the White Sea.

The following gives the data on the chemical composition of the fish raw materials were used.

Table 1. The chemical composition of fish raw materials.

| The name of indicators | Content, % | pollack blanched | MF |
|------------------------|------------|------------------|----|
| Moisture               |            | 78,9            | 53,0 |
| Protein, %             |            | 17,5            | 9,3  |
| Fat, %                 |            | 0,9             | 28,9 |
| Cinder, %              |            | 0,8             | 4,83 |

As can be seen from table 1, the mass fraction of moisture in the blanched pollock is 78.9%, which is 32.8% more than in MF stuff, where the value of this indicator is 53.0% [4-6]. The blanched pollock contains 17.5% of protein substances, which is 53.1% more than in MF, containing only 9.3% of protein substances. Thus, we can attribute the pollock blanched to protein products (15-20% of nitrogenous substances), and MF to low-protein products (up to 10% of nitrogenous substances).

At the same time, MF includes a lot of fat - 28.9%, the amount of fat in the pollock muscle tissue is only 0.9%. In addition, there were 4.82% of ash elements determined in MF, which is more than 6 times than in the blanched pollock, where only 0.8% were found.

Therefore, the putting on of MF into the fish paste, where pollock muscle tissue is used as the main raw material, leads to a decrease in the mass fraction of moisture and protein, but to an increase in the content of fat and minerals.

By varying the amount of the supplement of the MF added, one can obtain a product enriched with valuable fish oil and minerals.

The use of vegetable raw materials in the technology of preparation of pasty products improves the taste, aroma, texture of the product, gives it tenderness. In making experimental samples of fish pastes, there was an onion of an acute variety "Strigunovsky" used, that has good taste qualities, a high content of vitamins and biologically active substances. There was a carrot "Vitamined" used, it has a structure, matched to be chopped and it has a high content of vitamins. The chemical composition of raw vegetables is presented in Table 2.

Table 2. The chemical composition of vegetables raw materials.

| The name of components | Content, % | carrot boiled | onion browned |
|------------------------|------------|---------------|---------------|
| Water                  |            | 90,4          | 68,6          |
| Proteins               |            | 1,2           | 2,0           |
| Fats                   |            | 0,1           | 14,8          |
| Carbs                  |            | 6,1           | 12,0          |
| Food Fibers            |            | 1,2           | 1,0           |
As can be seen from Table 2, the use of vegetable raw materials in the production of fish-pasty products allows you to further enrich it with carbons, food fibers [7].

To improve the taste properties, there was salt added in the amount of 1.5% and a ground black pepper, which has antioxidant properties due to the content in it of up to 2.1% of essential oils. Formulations of experimental samples of fish pastes are presented in Table 3.

**Table 3. Recipes of the experimental samples of fish pastes (kg per 100 kg of product).**

| The name of components          | Quantity, % | sample No 1 | sample No 2 | sample No 3 | sample No 4 |
|--------------------------------|-------------|-------------|-------------|-------------|-------------|
| Pollack blanched               | 35.0        | 52.5        | 59.5        | 70.0        |             |
| Minced fish                    | 35.0        | 17.5        | 10.5        |             |             |
| Carrot boiled                  | 12.0        | 12.0        | 12.0        | 12.0        |             |
| Onion browned                  | 5.5         | 5.5         | 5.5         |             |             |
| Water                          | 8.0         | 8.0         | 8.0         |             |             |
| Starch modified (phosphate)    | 3.0         | 3.0         | 3.0         |             |             |
| Salt                           | 1.5         | 1.5         | 1.5         |             |             |
| Pepper black ground            | 0.3         | 0.3         | 0.3         |             |             |
| Sorbate potassium              | 0.1         | 0.1         | 0.1         |             |             |

In order to increase the stability of fish pastes during storage, there was a chemical preservative injected — a potassium sorbate in an amount of 0.1%. A potassium sorbate exhibits a fungistic effect, inhibiting the development of yeast and mold fungi, including aflatoxin-forming ones, due to its ability to inhibit enzymes. Antimicrobial action of this additive does not depend on the pH of the environment.

Sorbic acid and its salts are the safest and most highly effective preservatives, which have been thoroughly studied by toxicologists, approved and resolved all over the world. They are included in the list of “Food additives that do not adversely affect human health when used for the manufacture of food products” (Appendix No. 7 to SanPin 2.3.2.1078-01). Potassium sorbate protects food products not only during processing and storage, but also after opening the consumer packaging. Technologically, potassium sorbate is convenient in operation, since it is highly soluble in water [8-10].

To obtain the necessary rheological properties of the products and to form the consistency, a modified starch (phosphate) was used as a thickener. Unlike vegetable starch, which is considered a food product, modified starch is a food additive.

In the course of the research, an organoleptic evaluation of the quality of experimental samples of fish pastes was carried out.

In order to ensure high reliability of the results of expert assessment of the quality of pastes, the tasting was carried out by a permanent composition of trained tasters including developers of processing equipment, technologists and representatives of retail chains.

The concordance of an expert group was evaluated by Kendall's criteria [11-12]

\[
W = \frac{12S}{m^2(n^2-n)},
\]

\( m \) - amount of experts in the group,

\( n \) - amount of the factors,

\( S \) - the sum of squares of rank differences (deviations from the mean), calculated by the formula:

\[
S = \sum_{j=1}^{n} \left( \sum_{i=1}^{m} Aij - \frac{1}{2} m(n+1) \right)^2,
\]

The value of such a criterion was equal to 0.87 and indicates the consistency of expert opinions. As descriptors were chosen: appearance; color; smell; taste; consistence; quality of the level.
3. The results and discussion

The results of expert evaluation operations were filled into the tasting lists, which were subjected to statistical processing as follows: the average scores of tasters for individual indicators and the calculation of the arithmetic mean value of the assessment of individual indicators (in points). The results of the organoleptic evaluation and indicators of the level of quality are presented in Table 4.

Table 4. Organoleptic evaluation and indicators of the level of quality of the investigated fish pastes.

| Name of indicators | Factor of importance | The average estimated score for samples | Comprehensive assessment of samples |
|--------------------|----------------------|----------------------------------------|-----------------------------------|
|                    |                      | No 2 | No 3 | No 4 | No 5 | No 2 | No 3 | No 4 | No 5 |
| appearance         | 2                    | 4.0  | 4.7  | 4.7  | 4.6  | 8.0  | 9.4  | 9.4  | 9.2  |
| color              | 2                    | 4.8  | 4.8  | 4.8  | 4.7  | 9.6  | 9.6  | 9.6  | 9.4  |
| smell              | 6                    | 4.2  | 4.8  | 4.8  | 4.7  | 25.2 | 28.8 | 28.8 | 28.2 |
| taste              | 6                    | 4.4  | 4.9  | 4.6  | 4.6  | 26.4 | 29.4 | 27.6 | 27.6 |
| consistence        | 4                    | 4.2  | 4.8  | 4.5  | 4.5  | 16.8 | 19.2 | 18.0 | 18.0 |
| quality of the level | 20                 |      |      |      |      | 86.0 | 96.4 | 93.4 | 92.4 |

The coefficients of the weights of indicators are used at the stage when calculating the complex indicator, which is the sum of the given estimated single indicators for the corresponding coefficients of the weight of the indicators [13-15]. For individual and complex indicators set the quality level of the investigated fish pastes.

From the Table 4 it can be seen that the quality level of the studied samples is from 86.0 to 96.4 points. However, the highest level of quality - 96.4 points falls on sample No. 2.

According to such indicators as color, smell, consistence, this sample was rated in 4.8 points, taste - 4.9, appearance - 4.7 points. The closest to sample No. 2 in quality level — 93.4 points is sample No. 3. Due to the fact that its taste was less intensely pronounced, and the consistence was not sufficiently juicy these indicators were rated in 4.6 and 4.5 points respectively, which led to a decrease in the level of quality compared with sample No 2.

Experts quite appreciated the quality level of sample No 4 - 92.4. In this sample, the indicators of color, smell received a rating in 4.7 points, appearance and taste in 4.6 points, consistence - 4.5 points. Some reduction in the scoring is due to the fact that this sample showed slight incrustations of skin particles, the color was less attractive, the taste and smell was less pronounced, the texture was rather dry.

Sample No. 1 had a high level of quality - 86.0 points, but low single points: in appearance - 4.0 points due to the presence of incrustations of skin particles, in smell - 4.2 points due to insufficient expression, taste - 4.4 points due to a slight bitterness, the consistence - 4.2 points, since it was somewhat watery [16-18].

On the basis of the developed formulations (see Table 3) and taking into account the organoleptic parameters, the optimum amount of MF used in the preparation of fish pastes was determined - 25%. Introducing it in larger quantities reduces the quality of the product, making the taste somewhat bitter, the consistence is liquid, the appearance less attractive. The addition of MF in the proposed amount has a positive effect on the organoleptic properties of products, making the taste and smell more pronounced, the consistence is juicier.

The results of processing in order to verify the reliability of the expert estimates showed that the confidence intervals of the average score of the organoleptic evaluation of the studied samples of fish pastes are the following: sample No 1 [4.18 – 4.46]; sample No 2 [4.8]; sample No 3 [4.58 – 4.78]; sample No 5 [4.56 – 4.68].
As follows from the obtained data, samples No. 3 and 4 do not significantly differ from each other. Samples No. 1, 2, 3 and No. 1, 2, 4 significantly differ from each other according to the results of sensory evaluation. The introduction of various additives in the production of pasty fish products leads to a change in the structure of the product and its associated rheological characteristics. To predict the hydrodynamic situation in the product zone of technological machines and devices in the production of fish pastes, it is necessary to know the patterns of product behavior under shear deformation [19].

Dependence of the logarithm of the effective viscosity of fish paste on the velocity gradient is presented in the Fig. 2.

\[ f_1(x) - \text{fish paste from MF additive}; f_2(x) - \text{fish paste with addition 30\% MF}; f_3(x) - \text{fish paste with addition 15\% MF}; f_4(x) - \text{fish paste with addition 9\% MF}; f_5(x) - \text{fish paste without any additives}. \]

**Figure 1.** Dependence of the logarithm of the effective viscosity of fish paste on the velocity gradient (on the forward course of the reotest).

**Figure 2.** Dependence of the logarithm of the effective viscosity of the fish paste on the velocity gradient (on the reverse course of the reotest).

Using rheological methods of studies, as revealed by the results of research, it is possible to detect even minor changes in the structure of the object being studied, as well as to control the technological process at all its stages in order to obtain a finished product with predetermined properties. In addition, knowledge of the rheological characteristics makes it possible to most accurately make calculations of the working bodies of machines and units. On the other hand, the assessment of the consistency of the finished product is very subjective [20-21].

From the standpoint of physical mechanics, the consistency affects the ability of the material under study to resist the development of residual deformations under the influence of external forces. At the same time, a complex of rheological properties is found: elasticity, strength, viscosity. Determining the consistency of fish pastes in merchandising practice is carried out by the organoleptic method when chewed simultaneously with the assessment of taste. Organoleptic evaluation is characterized by descriptive terminology, the ambiguous interpretation of which leads to controversial situations.
4. Conclusion
The research results showed that the objectification of sensory consistency assessment by using scoring scales increases the accuracy of the determination, but does not provide complete comparable information on the numerical values of the consistency. Only an instrumental definition of such an important indicator as consistency, which is one of the defining indicators of such products as fish pastes, makes it possible to judge quite objectively, for example, of their most important performance properties, for example, formability.

Regardless of the assortment, this product must have a uniform, juicy, fibrous and consistency without any chopped bones. That is why instrumental methods for determining consistency are often simply necessary to evaluate this one of the most important indicators of pasty production.

According to the results of the analysis of the constructed rheogram, the dependence of the logarithm of the effective viscosity of fish paste samples on the logarithm of the velocity gradient on the “forward” (Fig. 1) and “reverse” (Fig. 2) of the reotest, it can be said that the amount of MF additive in fish paste significantly affects the structural and mechanical characteristics of the product. The nature of this influence is different for the original structure (on the direct course of the reotest) and the structure subjected to mechanical stress (on the reverse course of the reotest).

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