A resource saving technology for industrial processing of deep-sea and demersal fishes

L D Petrova

Far Eastern Federal University, Campus, 10 Ajax Bay, Russky Island, Vladivostok, 690090, Russia

E-mail: Petrova_ld@mail.ru

Abstract. This article shows the results of testing the technology of producing combined fish farce from deep-sea and demersal fishes. The object of our research is frozen fish, such as Giant grenadier (Albatrossia pectoralis), Alaska plaice (Pleuronectes quadrituberculatus), Pacific halibut (Hippoglossus stenolepis) and Pacific ocean perch (Sebastes alutus). We found out that a combination of Giant grenadier (Albatrossia pectoralis) and demersal fishes, such as Alaska plaice (Pleuronectes quadrituberculatus), Pacific halibut (Hippoglossus stenolepis) and Pacific ocean perch (Sebastes alutus) in the proportion of 50:50 and a certain salt curing method make it possible to produce high-quality farce systems. We provide a scientific basis for the certain technological parameters defining the formation process of farce system texture depending on the quantity of sodium chloride, temperature of salt curing and length of curing. We found out that sodium chloride at a rate of 1.5-2.0% increases rheological properties of combined fish farce. We outlined conditions and parameters of technological treatment affecting the quality characteristics of ground fish muscle of giant grenadier (Albatrossia pectoralis) with preliminary salt curing. We found out that the highest values of adhesiveness, viscosity, water retention capacity and yield strength belong to experimental samples with 1.5-2.0% of sodium chloride to the raw mass with the temperature of curing plus 20±2ºC and reasonable curing time of about 15-20 minutes. Based on the data obtained, it seems promising to produce combined fish farce from deep-sea and demersal fishes, since this method makes it possible to improve their functional and technological properties and to increase consumption of deep-sea and demersal fishes for food.

1. Introduction

Modern industry development is based on innovative and resource-saving technologies. Implementation of resource-saving technologies involves use of low quality raw to produce high-quality and safe products. Fish industry development in this area means rational and complex processing of hydrobyonts aimed at saving natural resources.

A major fish catching region of Russia is the Russian Far East, which possesses 60% of fish resource reserves. Analysis of fish harvesting situation in the Far East basin within the recent years shows that catch of traditional wild-caught fishes declined, while catch of less valuable fishes increased. A positive trend of harvest increase is demonstrated by deep-sea and demersal fishes, which annual catch varies between 60 and 65% of the total volume of harvesting. The largest number in the group of deep-sea and demersal fishes belongs to grenadiers (rattails), plaices, halibuts, and rockfishes. Data of Fishery Agency for the Russian Far East basin show that from 2015 to 2017, the
Volumes of actual catch of these fishes show growth dynamics; thus, catch of plaices increased from 70.142 to 77.259 thousand tons; halibuts, from 14.478 to 16.163 thousand tons; rockfishes, from 1.736 to 2.158 thousand tons. Volumes of catch of grenadiers increased up to 17.330 thousand tons in 2017, which is 2.667 thousand tons more than in 2016 [1, 2].

Deep-sea and demersal fishes are poorly suitable for production of fish products with the use of traditional technologies and do not enjoy adequate demand of fish processing industry [3-7]. The main type of product produced from deep-sea and demersal fishes is frozen fish trunk.

Based on the above said, one may conclude that there is a need to conduct research in order to develop technologies, search for innovative approaches and improve the ways of processing deep-sea and demersal fishes.

The objective of this work is development of resource-saving technology based on complex processing of deep-sea and demersal fishes and producing combined fish farce systems of high-quality level.

2. Materials and methods
The object of our research is frozen fish: deep-sea fishes – Giant grenadier (Albatrossia pectoralis), and demersal fishes – Pacific ocean perch (Sebastes alutus), Alaska plaice (Pleuronectes quadrituberculatus), and Pacific halibut (Hippoglossus stenolepis), which have been stored at a temperature of minus 18 °C for not more than 3 months, and which are complying with GOST 32366–2013 standard “Frozen Fish. Chemical composition and water-retaining capacity (WRC) of fish farces was determined in accordance with GOST 7636-85 Fish, marine mammals, marine invertebrates and products produced from the same. Analysis methods”. Water Content Ratio (WCR) was calculated as a relation of mass fraction of water towards the total protein content in the muscular tissue [8]. Research of structural and mechanical properties of fish farce systems, such as adhesiveness, viscosity, yield value (YV) was performed with the help of Fudoh Rheometer RT-2015. Losses of mass of experimental samples during the heat treatment were determined by weighting method before and after thermal treatment.

3. Results of Research and their Discussion
The authors carried out analysis of chemical composition and functional and technological properties of deep-sea and demersal fishes (Tables 1, 2).

Table 1. Chemical composition and water ratio of proteins (Rw) of muscular tissue of fishes under study [3, 4, 6, 7].

| Fish                                      | Water (%) | Protein (N×6.25) | Lipids (%) | Minerals (%) | Rw (%) |
|-------------------------------------------|-----------|-----------------|------------|--------------|-------|
| Giant grenadier (Albatrossia pectoralis)  | 90.0-93.2 | 7.5-8.1         | 0.3-1.2    | 1.0-1.4      | 12.0  |
| Alaska plaice (Pleuronectes quadrituberculatus) | 77.3-78.8 | 17.7-18.9       | 1.7-3.7    | 1.1-1.4      | 4.5   |
| Pacific ocean perch (Sebastes alutus)    | 76.9-78.3 | 18.2-20.1       | 3.3-7.0    | 1.1-1.4      | 4.2   |
| Pacific halibut (Hippoglossus stenolepis)| 76.9-80.0 | 14.5-18.0       | 1.0-3.4    | 1.0-1.3      | 5.3   |
Results of study of chemical composition (Table 1) show that muscular tissue of Giant grenadier has high water content – 90-93.2%, while for demersal fishes: rockfish, plaice and halibut, this parameter is between 76.9 and 80.0%.

High parameter of water ratio of proteins (Rw) 12.0 is typical for grenadier, which is a sign of excessive water in the muscular tissue, which connection with hydrophylic protein systems is weakening, as a result, any thermal treatment leads to intensive dewatering of muscular tissue [6].

Demersal fishes have the highest content of protein (Table 1): from 14.5 to 20.1%, grenadier has the lowest content: 7.5-8.1%. As for the lipid content (Table 1), plaices, halibuts, and rockfishes belong to medium-fat fishes (from 2 to 8% of fat), grenadier – to lean fishes (up to 2% of fat) [8]. Muscular tissue of fishes under study contains a significant quantity of minerals (from 0.8 to 1.4%), which adds to its nutritional value.

Table 2. Functional and technological properties of ground muscular tissues of fishes under study [3, 4].

| Fish type                        | WRC, % | CSS, Pa | Losses during thermal treatment | Organoleptic Properties | Texture | Forming capability | Color |
|----------------------------------|--------|---------|---------------------------------|-------------------------|---------|--------------------|-------|
| Giant grenadier (Albatrossia pectoralis) | 37.7   | 18.9    | 64.8                            | Liquideous              | Does not take form | White  |
| Alaska plaice (Pleuronectes quadrituberculatus) | 53.2   | 510.3   | 22.1                            | Farce-like              | Good    | White              |
| Pacific ocean perch (Sebastes alutus) | 55.6   | 531.9   | 18.2                            | Farce-like              | Good    | White              |
| Pacific halibut (Hippoglossus stenolepis) | 52.7   | 450.1   | 23.8                            | Farce-like              | Good    | White              |

Data of Table 2 show that farces from plaice, halibut, and rockfish take form well, retain water better and have a firmer texture. White farce from grenadier has a liquideous texture, poor formability, poorer water retaining capacity (WRC 37.7%) and low resistance to shear characteristics (critical shear stress (CSS) 18.9 Pa), which leads to big losses of tissue juice after thermal treatment (64.8%).

Based on research conducted, one may conclude that combining ground muscular tissue of Giant grenadier and demersal fishes makes it possible to form farce compositions with improved functional and technological properties and prescribed structure.

As it is known from literary sources [9-11], to improve functional and technological properties (FTP) of farce systems, a method of combining several fishes is applied. Farce from each type of fish, depending on its chemical composition, has different structural and mechanical, rheological and organoleptic properties, and their combination makes it possible to obtain farce compositions required to produce high quality products.

Literature data [9-12] show that in order to structure the properties of farce systems, muscular tissues of fishes, coarse and fine ground, are used as a binding agent, which makes it possible to make the products with the prescribed FTP and structure.
For production of shaped farced products from frozen raw, to improve their structural and mechanical properties and obtain the required texture, sodium chloride is used. Adding sodium chloride to ground fish mass increases its level of solubility of myofibrillar proteins, this way raising their gel-forming capability, which leads to increase of adhesive properties and firmer texture of finished products [9, 10, 13].

For development of combined farce systems, muscular tissue if Giant grenadier is used as a main component, which has water content over 90% and low structural and mechanical, as well as organoleptic properties. In the farce systems, the quantity of ground muscular tissue of Giant grenadier is at least 50% of the farce mass. Grenadier fillet is cut into chunks, since it has liquidous texture after grinding. Preliminary studies showed that the most efficient method of treating grenadier is its cutting into chunks of 1-5 grams each. Research of rheological properties and organoleptic parameters brings to the conclusion that the optimal quantity of sodium chloride to be added to face is 1.5-2.0%. When adding sodium chloride to fish farce systems at the rate of 1.0, 2.0, 3.0, and 4.0% of the total farce mass, their adhesiveness and viscosity increases 1.5-2.2 times as compared with unsalted samples. However, adding over 2.0% of sodium chloride to the ground muscular tissue of fish has a negative impact on its organoleptic properties: fish mass becomes too salty.

When preparing experimental samples, Giant grenadier is defrosted to the temperature of 0… –2 ºC, filleted, cut into chunks of 1-5 gram each, and then add sodium chloride at the rate of 1.5-2.0% of muscular tissue. To improve functional and technological properties of farce systems from Giant grenadier, farces made from demersal fishes are added as a binding agent. Chunks of Giant Grenadier of 1-5 gram each are added to the ground fish farce (screen hole diameter 3-7 mm) of Pacific ocean perch (Sebastes alutus), or Alaska plaice (Pleuronectes quadrituberculatus), or Pacific halibut (Hippoglossus stenolepis). Then it is mixed in the fish farce mixer at a rotation speed of 1,500 rpm for 2-3 minutes.

We have studied the influence made by proportion of grenadier chunks and finely ground farce of Alaska plaice (Pleuronectes quadrituberculatus), or Pacific halibut (Hippoglossus stenolepis), or Pacific ocean perch (Sebastes alutus) 70:30; 60:40; 50:50 respectively on water retaining capacity (WRC) and critical shear stress (CSS) of farce systems. Based on conducted studies, we have found out that adding finely ground farce of demersal fishes has a positive impact on texture of farce compositions, which is evidently explained by increase of protein content in the farce systems, which have a significant influence on the farce texture formation. The highest WRC (46.5 to 48.6%) and CSS (480.8 to 506.8 Pa) values were registered for experimental samples from ground muscular tissue of demersal fishes and grenadier in proportion of 50:50. However, WRC parameters of combined farces do not reach the required value over 50% and are characterized by low forming capability. According to the literature data [14], if farce WRC is below 50%, it is poorly suitable for production of shaped farce products.

To improve functional and technological properties of farce compositions, we applied the method of preliminary salt curing of Giant grenadier chunks. For the purpose of justification of salt curing method use, we researched the impact of sodium chloride, temperature and length of curing on FTP of muscular tissue lumps of Giant grenadier. In the experimental samples, the content of sodium chloride is 1.5-2.0%. The temperature range of plus 20±2 ºC is applied based on research data.

We have studied the methods of salt curing at various temperatures. Temperature intervals are applied based on recommended temperature for various types of salt curing: cold salt curing has an interval from minus 1 to minus 3°C [9, 10]; for warm salt curing, the interval is from plus 8 to plus 12°C and from plus 18 to plus 22°C [15]. Experimental data show that there is a tendency of increase of adhesiveness and viscosity of Giant grenadier ground muscular tissue depending on the temperature and length of curing. Maximum value of adhesiveness of farce system, 14.5 Pa, is observed at the curing temperature plus 20±2ºC, while at the temperature plus 10±2°C and minus 3±2°C this value is 8.6 and 6.0 Pa respectively. Experimental sample, which curing process takes place at the temperature of minus 3±2°C, has low viscosity of 10.2 Pa. Raising temperature to plus 20±2°C and plus 10±2°C leads to increase of farce viscosity by 2.5 times and 1.3 times respectively, as compared with salt
curing at the below-zero temperature. Research results show that the optimal curing temperature for salt curing of ground muscular tissue of grenadier is plus 20±2ºC, when the content of free water in the system decreases, and adding sodium chloride increases solubility of proteins, this way improving adhesiveness and viscosity of farce [15].

To prepare model samples, grenadier fillet is cut into chunks of 1-5 gram each, sodium chloride is added at the rate of 1.5-2.0% of the total mass, and then it is mixed and cured at the temperature plus 20±2ºC. After the salt curing process is finished, finely ground farce of demersal fishes is added to the resulting mass in the proportion of 50:50, sodium chloride is added at the rate of 1.5-2.0% of farce mass, and then the mass is mixed in the fish farce mixer at a rotation speed of 1,500 rpm for 2-3 minutes.

As it can be seen from analysis of experimental data (Figure 1, 2), during the salt curing process, maximum parameters of WRC (from 51.8 to 53.2 %) and CSS (from 536.1 to 548.6 Pa) of farce compositions are observed within the period of 10-15 minutes. Salt curing for a longer period leads to decrease of these parameters, which is apparently explained by separation of a significant quantity of free water and, as a result, destruction of the farce system texture.

Figure 1. Dependence of farce systems WRC on the length of salt curing of ground muscular tissue of grenadier and demersal fishes: 1 - Pacific ocean perch (Sebastes alutus); 2 - Alaska plaice (Pleuronectes quadrituberculatus); 3 - Pacific halibut (Hippoglossus stenolepis).

Figure 2. Dependence of farce systems CSS on the length of salt curing of ground muscular tissue of grenadier and demersal fishes: 1 - Pacific ocean perch (Sebastes alutus); 2 - Alaska plaice (Pleuronectes quadrituberculatus); 3 - Pacific halibut (Hippoglossus stenolepis).
Based on conducted studies, one may conclude that the reasonable length of salt curing of ground muscular tissue of grenadier is the 10-15-minute interval, after which no significant WRC and CSS growth is observed.

We also studied functional and technological parameters of combined farce systems. As a control sample, we studied the parameters of ground muscular tissue of Giant grenadier.

**Table 3. Functional and technological properties of farce systems from Giant grenadier and demersal fishes**

| No. of farce composition | Farce composition (proportion) | WRC, % | CSS, Pa | Farce color, scores | Forming capability, scores |
|--------------------------|--------------------------------|--------|--------|---------------------|---------------------------|
| 1                        | Grenadier (control sample)     | 37.7   | 18.9   | 5                   | 1                         |
| 2                        | Grenadier + rockfish (50:50)   | 53.2   | 548.6  | 5                   | 4                         |
| 3                        | Grenadier + plaice (50:50)     | 52.9   | 541.8  | 5                   | 4                         |
| 4                        | Grenadier + halibut (50:50)    | 51.8   | 532.3  | 5                   | 4                         |

Research results show that in all farce systems developed, WRC and CSS parameters are higher than in the control sample (Table 3). The highest value of WRC (from 532.3 to 548.6 Pa) and the highest density of muscular tissue are registered in the samples of Giant grenadier and demersal fishes. High WRC parameters (from 51.8 to 53.2 %) are registered for the following samples: grenadier + rockfish (50:50); grenadier + plaice (50:50) and grenadier + halibut (50:50), which is on average 1.4 times higher than for the control sample. At the WRC values over 50%, the farce compositions show good forming capability; besides, all developed samples have white color.

We studied chemical parameters and energy values of farce systems (Table 4).

**Table 4. Functional and technological properties of farce systems from Giant grenadier and demersal fishes**

| Parameters         | Grenadier (control sample) | Grenadier + rockfish (50:50) | Grenadier + plaice (50:50) | Grenadier + halibut (50:50) |
|--------------------|----------------------------|-------------------------------|-----------------------------|-----------------------------|
| Water, %           | 90.7±0.3                   | 77.1±0.3                      | 77.7±0.3                    | 78.3±0.3                    |
| Protein (N×6.25), %| 7.5±0.3                    | 17.8±0.3                      | 17.6±0.3                    | 17.1±0.3                    |
| Lipids, %          | 0.6±0.3                    | 3.7±0.3                       | 3.2±0.3                     | 3.2±0.3                     |
| Minerals, %        | 1.2±0.3                    | 1.4±0.3                       | 1.5±0.3                     | 1.4±0.3                     |
| Energy value, kcal/kJ | 36.6/154.9               | 105.9/446.2                  | 100.7/424.4                | 98.6/415.5                 |

Comparative analysis of the chemical composition of farce compositions (Table 4) confirmed dependence of chemical composition on the way of combining farce from Giant grenadier and demersal fishes.
In the farce systems developed, as compared with the ground muscular tissue of grenadier, the content of protein is high enough, varying from 17.1 to 17.8%, which parameter classifies them as a source of complete protein. Experimental samples differ from ground muscular tissue of grenadier by high lipid content from 3.2 to 3.7%, while for ground muscular tissue of grenadier this value is 0.6%. Developed farce compositions are classified as medium-fat raw with lipid content up to 6.0% [8]. Mineral values in the farce compositions are 1.2 times higher as compared with the ground muscular tissue of grenadier.

Energy value of combined systems (Table 4) is on the average 2.7 times higher than that of the Giant grenadier farce and varies from 98.6 to 105.9 kcal, and from 415.5 to 446.2 kJ, apparently, because of higher protein and lipid content in the ground muscular tissue of demersal fishes.

Evaluating the particulars of chemical composition and functional and technological properties of combined farce systems from Giant grenadier and demersal fishes, one should note that they may be used as additional sources of protein for production of shaped farce products and are characterized by improved density and forming capability.

Therefore, muscular tissues of deep-sea and demersal fishes may be used for production of shaped farce products, while the method of combining farce from Giant grenadier and Pacific ocean perch (Sebastes alutus), or Alaska plaice (Pleuronectes quadrituberculatus), or Pacific halibut (Hippoglossus stenolepis) improves their functional and technological properties (adhesiveness, viscosity, WRC, CSS) and nutritional value.

4. Conclusion

We gave scientific evidence to the technological parameters of combining farce from Giant grenadier and Pacific ocean perch (Sebastes alutus), or Alaska plaice (Pleuronectes quadrituberculatus), or Pacific halibut (Hippoglossus stenolepis). We investigated the influence of proportion between the chunk raw from Giant grenadier and ground muscular tissue of demersal fishes on the functional properties of combined farce. We found that the highest WRC parameters (from 46.5 to 48.6 %), and CSS parameters (from 480.8 to 506.8 Pa) are registered for the experimental samples made in proportion 50:50.

We researched the impact of sodium chloride, temperature and length of curing on rheological properties of chunks of grenadier muscular tissue under preliminary salt curing. We established that during salt curing of chunks of 1-5 gram each, the maxmum WRC, viscosity, adhesiveness and CSS parameters are observed at the temperature of plus 20±2ºС within 10-15 minutes with sodium chloride added at the rate of 1.5-2.0% of the total farce mass.

Study of chemical composition and functional and technological properties of combined farce systems showed that these farce systems have high nutritional value and better texture as compared with ground muscular tissue of grenadier.

Therefore, developed resource-saving technologies of making combined farce systems make it possible to produce high-quality food products, raise the level of use of deep-sea and demersal fishes for food, thus making a significant contribution to the development of the country and regional economy.

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