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A study of combined minced meat from hydrobionts for snacks

Dementieva Natalia Valerievna, Boitsova Tatiana Maryanovna, Bogdanov Valeryi Dmitrievich*

Department of Technology of Food Products, Far Eastern State Technical Fisheries University, Vladivostok, Russian Federation

**Corresponding author: dnvdd@mail.ru*

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Abstract: This paper considers the developments whose application is promising for the fishing industry under the production of dried snack products. Fish chips are non-traditional dried products. The goal of this research was to study the functional and technological properties of minced systems consisting of fish and seafood. Minced systems were pre-treated with special food additives to improve their rheological properties and organoleptic indicators. The objects of research were stuffed meat products which included 65% to 75% of pollock, 15% of Pacific herring, and 10% to 20% of seafood. A study of technochemical indicators showed that minced systems were high-protein. They contained 30.0–34.8% of protein, 2.2–3.7% of lipids, and 0.8–2.5% of carbohydrates. Minced systems made of hydrobionts are characterised by the high water-holding capacity of 74.52–90.3%, which indicates good lyophilic properties of raw materials. When studying the rheological parameters of minced systems from hydrobionts, it was found that the maximum shift tension was 6.0–8.1 kPa. The stickiness index was 2 400–3 200 Pa, the dynamic viscosity was within the range of 650–850 Pa s (pascal seconds). The effective viscosity index for fish mince with good mouldability is 600–900 Pa s. The organoleptic evaluation showed that minced systems from hydrobionts pre-treated with food additives had high sensory characteristics.

Keywords: seafood; minced systems; food additives; chemical composition; rheological properties; sensory characteristics

In recent years, there has been an increase in the market segment of dried-jerked fish products, the range of which has constantly been expanding in the world. The goal of the research is to study the functional and technological properties of combined minced systems consisting of fish and seafood, pre-processed with special food additives, with the aim of using them in the technology of dried chips.

The fish processing industry currently produces a diverse range of products. Along with salted, smoked fish, canned goods, and preserves, the market segment is occupied by dried and jerked fish products, while the range of these products in the world is constantly expanding. This trend is associated with the introduction of new technologies into production, the use of unconventional types of fish raw materials, as well as consumer demand for new high-quality products (Mozaffarian and Rimm 2006; Antipova and Kalach 2011; Heising et al. 2014).

In order to remain competitive in the market, fish processing enterprises constantly need to improve the range of products and update them by introducing new products with high organoleptic characteristics into production (Antipova et al. 2010; Kaya and Baştürk 2015; Ucak and Gokoglu 2016).

Unconventional dried products are fish chips, which, unlike chips made from vegetable raw materials, are characterised not only by high taste, but also by in-

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creased nutritional and biological value. It is known that for the production of fish chips, it is necessary to cook minced meat, and then add components that play the role of flavouring and structure-forming substances (Holley and Patel 2005; Okpanachi et al. 2018). As a raw material for fish chips, it is possible to use a low cost fish, as well as high-value food waste from crustaceans and molluscs that remain after the production of other types of fish products (canned food, preserves, etc.). These products have an acceptable cost, which makes them competitive in the modern market of snack products (Antipova and Kalach 2011; Heising et al. 2014).

MATERIAL AND METHODS

The objects of the study were minced systems of pollock muscle tissue, Pacific herring, and food waste from production of squid, shrimp, and mussels. The shelf life of frozen fish used for the production of minced meat did not exceed 6 months at a temperature of minus 18 °C. The quality of the raw materials met the requirements of regulatory documents.

Minced meat was prepared according to the recipes we proposed in kg per 100 kg:

- recipe 1: pollock (70%), herring (15%), shrimp (15%);
- recipe 2: pollock (75%), herring (15%), squid (10%);
- recipe 3: pollock (65%), herring (15%), mussel (20%);
- recipe 4: pollock (70%), herring (15%), shrimp (5%), squid (5%), mussel (5%);
- recipe 5: pollock (70%), shrimp 10%), squid (10%), mussel (10%).

The fish was preliminarily defrosted and cut into skinless fillets. The resulting fish fillets and food waste from cutting squid, mussels, and shrimp were washed in running water and sent for grinding. Grinding of raw materials to obtain minced meat was carried out using a meat grinder plate with the hole size of 3 mm.

For pretreatment of minced meat systems, a mixture of food components was prepared according to the recipe (kg per 100 kg): soy sauce (60%), linden honey (25%), edible salt (20%), dried paprika (3%), dried coriander (3%), and ground red pepper (1%).

Spices in the composition of the mixture are involved in the formation of organoleptic properties of the product and increase its storage stability. Table salt contributes to the formation of the structure of minced meat systems, exhibits preservation properties, and improves organoleptic characteristics. Honey increases the viscosity of the minced meat, forms an elastic structure and organoleptic characteristics of the finished product. Soy sauce increases the biological value, participates in the gelation process, and forms original organoleptic characteristics.

The food mixture was added to the minced meat in an amount of 20–25% to the mass of minced meat, and thoroughly mixed with the minced meat.

After processing the minced meat systems with a mixture of food additives, they were kept at a temperature of 15 °C for 1.5 h.

The amount of table salt was determined in the process of preliminary exposure of combined minced meats from hydrobionts, prepared according to different recipes and treated with a mixture of food additives to determine the degree of salting. In our study, we used the argentometric method for the determination of table salt. It is based on the interaction of sodium chloride with silver nitrate in the presence of potassium chromate with the formation of a red precipitate – silver chromate.

A 2–5 g sample of the minced meat sample, weighed with an absolute error of not more than 0.01 g, was placed in a volumetric flask with a capacity of 200–250 cm^3 and poured into three quarters of its volume with distilled water heated to 60 °C. The content of the flask was infused for 15–20 min, periodically shaking vigorously. At the end of the infusion, the liquid in the flask was cooled to room temperature; the volume was brought up to the mark with water. The content of the volumetric flask was thoroughly shaken and filtered through a dry paper filter. In two conical flasks, 10–25 cm^3 of the filtrate was taken and titrated with 0.1 mol dm^{-3} silver nitrate solution under the presence of 3–4 drops of 100 g dm^{-3} (10%) potassium chromate solution until the non-disappearing reddish-brown colour was obtained. The mass fraction of sodium chloride (X, %) was calculated by the formula:

$$X = \frac{0.00585KVV_1}{V_2 m} \times 100\ (\%) \tag{1}$$

where: V – the volume of the aqueous extract in a volumetric flask (cm^3); V_1 – the volume of 0.1 mol dm^{-3} silver nitrate solution, consumed for titration of the test solution (cm^3); V_2 – the volume of the aqueous extract taken for titration (cm^3); m – the weight of the test sample (g); 0.00585 – the amount of sodium chloride corresponding to 1 cm^3 of 0.1 mol dm^{-3} silver nitrate solution (g); K – the conversion factor for an exact solution of 0.1 mol dm^{-3} of silver nitrate.

The amount of fat was determined by the extraction method. The method is based on the extraction of fat from the product with an organic solvent – petroleum

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ether in the Soxhlet apparatus, evaporation of the solvent and determination of the mass of extracted fat by weighing.

The determination of total nitrogen was carried out by a method based on the oxidation of organic matter by burning it in sulphuric acid in the presence of a catalyst, distilling off the ammonia formed by steam, trapping it with a solution of sulphuric acid, and determining the nitrogen content by titration.

The mass fraction of water was determined by drying the product at a temperature of 100–105 °C and determining the mass by weighing it. Purified calcined sand (10−12 g) was placed in a clean dry bottle, the bottle with sand and a glass rod was placed in an oven (drying cabinet, FSO (WGLL)-625L; UED-Lab, Russia) and, after removing the lid, it was dried to constant weight. After closing the bottle with a lid in a drying cabinet, transfer it to a desiccator (2-240; Promkomplekt, Russia), cool (laboratory balance, DX-300WP; UED-Lab, Russia) and weigh. A sample of minced meat of 1.5 g to 5 g was placed in the same bottle, covered with a lid and weighed. Then the sample was thoroughly mixed with sand with a glass rod, the content was evenly distributed over the bottom of the weighing bottle. An open weighing bottle with minced meat was placed in an oven and dried for 4 h at a temperature of 100–105 °C. The buckets were covered with lids and cooled in a desiccator for 20−30 min and weighed. The mass fraction of water (X, %), was calculated by the formula:

$$X = \frac{\left(m_1 - m_2\right)}{m} \times 100\,(\%) \quad (2)$$

where: m – the weight of the sample (g); m_1 – the weight of the weighing bottle and sand before drying (g); m_2 – the weight of the weighing bottle and sand after drying (g).

The amount of mineral substances was determined by removing the organic substances from the product by burning in a muffle furnace at a temperature of 500 °C and determining the ash by weighing.

Determination of glycogen was carried out by hydrolysis of proteins with alkali, isolation of glycogen from the solution with ethanol, washing the glycogen and its dissolution, reaction with anthrone (colour development), and measuring the colour intensity. When heating the tissue samples with a concentrated alkali solution, protein hydrolysis occurs, with glycogen released from the cells. Glycogen does not dissolve in ethanol; it precipitates when a rather large volume is added. The addition of a few drops of concentrated sulphuric acid promotes the deposition of glycogen due to the formation of ammonium sulphate. Heating the washed glycogen precipitate with anthrone (a highly specific carbohydrate reagent) dissolved in concentrated sulphuric acid leads to the hydrolysis of glycogen to glucose due to the catalytic effect of sulphuric acid and to the development of colour during the reaction between glucose and anthrone. The amount of glucose was estimated by the colour intensity. Developing colour is proportional to the amount of glucose taken in the range from 10 μg to 100 μg in the sample. The reaction product coloured from green to blue-green had an absorption maximum at a wavelength of 620 nm. The colour intensity of the solution was measured by a spectrophotometer (PE-5400 UF; Profpribor, Russia) with a red filter with maximum transmission at the same wavelength.

The water-holding ability of minced meat (WHA) was determined by the pressing method, which is based on the separation of water from the sample during easy pressing, sorption of the released water by filter paper (grade FS Dezolennaya, 520 × 600 mm; Yugreaktiv, Russia) and the determination of the amount of separated water by the size of the spot area left by it in the filter paper. The reliability of the results is ensured by triplicate determinations.

An ashless filter of 9–11 cm in diameter (red tape, 110 mm; Yugreaktiv, Russia), preliminarily kept in a desiccator, with a KCI solution to standardise its moisture content, was placed on a plexiglass plate of 11 × 11 × 0.4 cm (OOO "Himtorg", Russia). A 0.3 g sample of minced meat was weighed on a scale on a polyethylene mug of 15–20 mm in diameter, after which it was transferred to the filter so that the sample was under the circle. From above, the sample was covered with the same plate as the lower one, a weight of 1 kg was placed on it and held for 10 min. After holding, the filter with a weighed portion was released from the load and plates, and the contour of the inner spot (the trace left by the minced meat) was drawn with a pencil. The outer contour was outlined when the filter paper dried in air. The areas of general and internal spots were determined. The size of the spot area left by the released water was calculated from the difference between the total area and the area of the inner spot. It has been experimentally determined that 1 cm^2 of the wet spot area corresponds to 8.4 mg of water. The water-holding capacity of minced meat (X) as a percentage is calculated by the formula:

$$X = \left(1 - \frac{8.4S}{M}\right) \times 100\,(\%) \quad (3)$$

https://doi.org/10.17221/264/2020-CJFS

where: S – wet spot area (mg); M – total mass of moisture in the sample (mg).

Effective viscosity and stickiness were determined using a Rheolograph Sol-535 instrument (Tokyo Seki Ltd., Japan). The ultimate shift tension was checked by a KZT-4 conical penetrometer designed by V.D. Kosoy (Russia).

Organoleptic evaluation of minced meat was carried out in accordance with the terminology of the description of the characteristics that are most common in practice, to characterise the organoleptic indicators of minced meat (Masilko et al. 2015). To conduct tastings, an expert commission was established, consisting of a working group and expert groups. The working group consisted of a leader, technical staff and an expert in evaluated products. Technical workers participated in the compilation of questionnaires, point scales, a survey of experts, and the processing of the results. The expert group included qualified fish processing technologists who underwent special training as tasters of fish products. The decision on the quality of products was made based on the results of expert assessments. A decision was considered adopted if at least two thirds of the experts voted for it.

For organoleptic evaluation, a point scale was developed (Table 1). The scale includes quality characteristics (appearance, texture, colour, taste after cooking,

Table 1. Scale for organoleptic quality assessment of minced systems of hydrobionts

Quality indicators	Description	Points
Appearance	homogeneous minced meat, with small pieces of seafood, without separation of the liquid	5
	homogeneous minced meat, with pieces of seafood, without separation of the liquid	4
	homogeneous minced meat, with small pieces of seafood, with small separation of the liquid	3
	heterogeneous minced meat, with pieces of seafood, with small separation of the liquid	2
	heterogeneous minced meat, with pieces of seafood, with high separation of the liquid	1
Texture	very dense, very sticky	5
	dense, less sticky	4
	dense, non-sticky	3
	non-dense, non-sticky	2
	non-dense, non-sticky, liquid	1
Colour	beige	5
	light brown	4
	dark brown	3
	dark grey with a brown tint	2
	dark grey	1
Smell	smell of seafood and spices	5
	smell of fish, with a hint of seafood and spices	4
	smell of fish and spices	3
	smell of fish, spices, with a slight odour of oxidised fat	2
	smell of fish, spices, with a strong odour of oxidised fat	1
Taste after cooking	pronounced taste of seafood and spices	5
	taste of seafood and spices	4
	fish flavour with a hint of spices	3
	fish taste with a hint of spices, a slight aftertaste of oxidised fat	2
	fish taste with a hint of spices, tangible taste of oxidised fat	1

https://doi.org/10.17221/264/2020-CJFS

smell). The minced meat was cooked at a temperature of 100–102 °C for 20–25 min then cooled to a temperature of 30–40 °C and tasted. A gradation of indicators was carried out, corresponding to the number of points of the selected scale (in our case, five-point).

In this study, the methods of mathematical, statistical, and graphical processing were applied using the Statistica 6.0 software packages from StatSoft, Inc. and Microsoft Excel 2007.

The measurement values (in Figures 1 and 2 and in Table 2) are presented in the form of $x \pm \Delta$ [where: x – the arithmetic mean of the measurements; Δ – the standard deviation (SD)]. According to standard methods for determining the indicators, Δ should not exceed 0.5% for the determination of water, protein, and lipids; for the determination of carbohydrates, Δ should not be higher than 0.02%; for the determination of mineral substances – not higher than 0.01%; for the determination of sodium chloride – 0.2%; for the determination of water-holding capacity – not higher than 1%. All the obtained values of Δ correspond to the required accuracy of the experiments performed.

The total error of direct measurements (presented in Figures 3–5) was determined by the formula:

$$\Delta x = \sqrt{\Delta x_{\alpha}^2 + \Delta x_{np}^2} \quad (4)$$

where: Δx_{α} – the random measurement error;
Δx_{np} – the absolute error of the device.

The Δx_{α} values were calculated for 95% and $t_{\alpha n}$ = 2.57 (Student's coefficient).

RESULTS AND DISCUSSION

The general chemical composition and energy value of minced systems of aquatic organisms were studied (Table 2).

A study of the general chemical composition showed that pre-treatment of minced systems with food additives contributes to a partial decrease of water in minced meat; the water content in them varies from 59.8% to 64.8% depending on the formulation, while its average value for minced meat from frozen fish is 70–80%. The smallest amount of water is in the minced system prepared according to recipe 1 (59.8%), which includes pollock, Pacific herring, and shrimp. This is due to a partial violation of covalent bonds in the protein chain and a decrease in the ability to retain water. In addition, shrimp proteins are characterised by the lowest WHA; the shrimp content in the minced system is 15%, the largest of the proposed recipes (Bogdanov and Volotka 2013).

Minced systems of hydrobionts are high-protein; they contain 30.0–34.8% of protein. By the fat content, minced meat can be classified as low-fat; the amount of lipids in them is 2.2–3.7%. This is because the pollock muscle tissue is characterised by a low fat content (0.2–1.0%), and the amount of Pacific herring in minced meat is small – 15%. The largest amount of lipids is in the minced system prepared according to recipe 3, which, in addition to minced pollock and herring, includes mussels (20%), which contain more fat than other seafood. Since the shrimp, squid, and mussels are part of the minced systems, they contain carbohydrates from 0.8% to 2.5%. The content of minerals in minced meat is 1.8–2.5%.

The energy value of minced systems from pollock, Pacific herring, and seafood ranges from 139.6 kcal to 161.4 kcal per 100 g of the product depending on the minced meat recipe. Such a range in data of energy value is associated with the content of different hydrobionts in minced meat systems, differing from each other in chemical composition. The minced system prepared according to recipe 1 (which includes pollock, Pacific herring, and shrimp) has the highest

Table 2. The chemical composition and energy value of minced systems from pollock, Pacific herring, and seafood

Minced meat recipe	Content (%, n = 3, mean ± Δ)					Energy value (kcal 100 g^{-1})
	water	protein	lipids	carbohydrates	minerals	
Recipe 1	59.8 ± 0.4	34.8 ± 0.1	1.8 ± 0.1	1.5 ± 0.020	2.1 ± 0.010	161.4
Recipe 2	64.8 ± 0.2	31.4 ± 0.4	1.2 ± 0.2	0.8 ± 0.015	1.8 ± 0.009	139.6
Recipe 3	62.4 ± 0.5	30.0 ± 0.3	3.7 ± 0.3	1.8 ± 0.010	2.1 ± 0.007	160.5
Recipe 4	63.2 ± 0.4	30.3 ± 0.5	2.5 ± 0.1	2.1 ± 0.020	1.9 ± 0.010	152.1
Recipe 5	62.6 ± 0.3	31.5 ± 0.1	0.9 ± 0.2	2.5 ± 0.009	2.5 ± 0.008	144.1

Δ – standard deviation (SD)

https://doi.org/10.17221/264/2020-CJFS

energy value – 161.4 kcal. The lowest one (139.6 kcal) is in the system which includes pollock, Pacific herring, and squid (recipe 2). This system contains a maximum amount of water – 64.8%, since the squid muscle tissue is sufficiently flooded, which is associated with a reduced energy value compared to other samples (Bogdanov and Volotka 2013).

A change in the content of table salt in minced systems during the preliminary processing of their food additives was observed for 1.5 h. The food mixture was added in an amount of 20–25% to the mass of minced meat, and thoroughly mixed with the minced meat. It has been experimentally determined that the use of a food mixture in an amount of 20–25% provides the necessary rheological characteristics of the minced meat mass and high organoleptic characteristics of the finished product. The inclusion of less than 20% of food mixture does not provide the necessary structure of the minced meat mass; an increase in the amount of food mixture to more than 25% leads to deterioration in the rheological and organoleptic characteristics of the finished product.

From the samples of minced meat prepared according to different recipes, an average sample was taken at time intervals of 10, 30, 60, and 90 min. An average sample of minced meat was passed through a filter cloth in order to separate the marinade, from which a sample of minced meat weighing 2 g to 5 g was taken for analysis. It was found that after 10 min of exposure, its amount was 0.01–0.04%. After 60 min, the salt content increased to 1.9–2.4%. By the end of the process, the salt content in the minced meat varied from 3.0% to 4.8% (Figure 1). When determining the salt in minced meat systems, all the components found there, including soy sauce, were taken into account. In the experiment, the degree of salting was compared depending on the formulation of the minced meat system.

More salt was contained in the minced system prepared according to recipe 5, in the composition of which there was no Pacific herring muscle tissue, therefore it had less fat, and the process of salt penetration into the system was faster than in the other samples.

The study has shown that the rational holding time of minced meat was 60–90 min, depending on the recipe, which provided the necessary salting and maturation of the minced meat mass.

After aging, the remains of the marinade were separated from the minced meat. Minced meat was rolled out into layers 0.3–0.5 cm thick, from which the chips of round, oval or other shape were formed. Then the chips were dehydrated at a temperature of 50–60 °C for 6–7 h, then cooled to room temperature (20–25 °C); the finished product was packed in 0.05 kg portions in plastic bags and evacuated at a pressure of 1.2 MPa.

Minced systems from pollock, Pacific herring, and seafood are characterised by high WHA values (from 74.52% to 90.3%), which indicates good lyophilic properties of raw materials used for the production of minced meat (Figure 2). The highest WHA is possessed by the minced system of pollock, Pacific herring, shrimp, squid, and mussels – 90.3% (recipe 4), the lowest (74.52%) by the minced system of pollock, Pacific herring, and shrimp (recipe 1). It is known that minced meat with a WHA index of more than 53% is well formed; products prepared on its basis have more monolithic and elastic consistency (Antipova and Voronkova 2013; Drozdetskaya and Berezovikova 2013; Drozdova and Pivnenko 2013; Drozdetskaya and Berezovikova 2018).

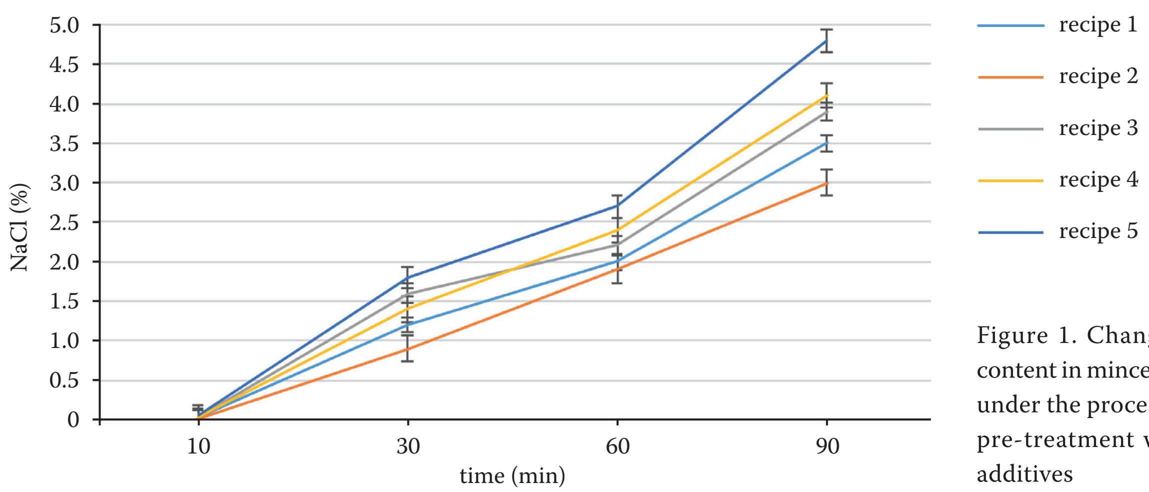

Figure 1. Change in salt content in minced systems under the process of their pre-treatment with food additives

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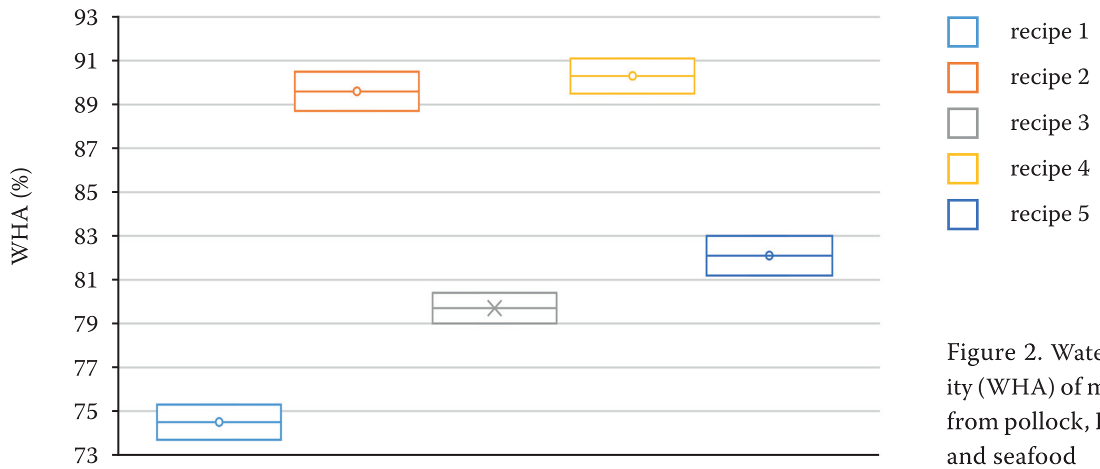

Figure 2. Water-holding ability (WHA) of minced systems from pollock, Pacific herring, and seafood

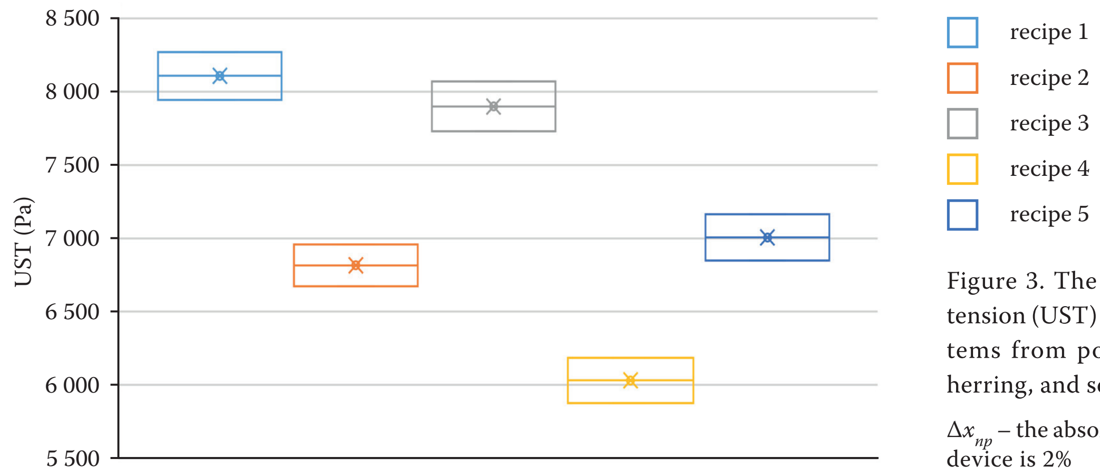

Figure 3. The ultimate shift tension (UST) of minced systems from pollock, Pacific herring, and seafood

Δx_{np} – the absolute error of the device is 2%

One of the indicators characterising the rheological properties of minced meat is the ultimate shift tension (UST). The UST of the investigated minced systems is 6.0–8.1 kPa (Figure 3). The highest value of UST is in the system prepared according to recipe 1 (8.1 kPa), the lowest value (6.0 kPa) in the system prepared according to recipe 4.

A well-known fact is the inverse correlation between the moisture content of the product and the ultimate shift tension. With an increase in the water holding capacity, stickiness, and elasticity of minced meat increase and UST decreases (Chernyshova and Tsibizova 2012; Zhang et al. 2013; Lupi et al. 2014; Wu et al. 2015; Suchenko et al. 2017). This dependence is consistent with our research, so in the minced system (recipe 4) with the highest WHA (90.3%) the UST value is lowest (6.0 kPa).

The stickiness of the minced systems from hydrobionts is 2 400–3 200 Pa. The highest stickiness (3 200 Pa) was found in minced meat from pollock, Pacific herring, squid, and mussels (recipe 4). Less sticky minced meat, in comparison with other samples, is from pollock, Pacific herring, and mussels (recipe 3); its stickiness is 2 400 Pa (Figure 4). Stickiness will contribute to the full formability of the workpieces when portioning the chips; in this case, recipes 1 and 4 can be recommended.

An important rheological indicator of minced meat necessary for moulding is its effective viscosity, on which the formability of minced meat directly depends. From the literature data, it is known that minced fish has a good moulding ability with effective viscosity values in the range of 600–900 Pa s (pascal seconds) with a single velocity gradient (Bogdanov and Volotka 2013).

For minced systems from pollock, Pacific herring, and seafood, the dynamic viscosity is in the range of 650–850 Pa s, that is, the minced meat prepared according to the recipes we offer is characterised by good formability (Figure 5).

The rheological characteristics of minced meat are affected by the fat content in raw materials (Heising

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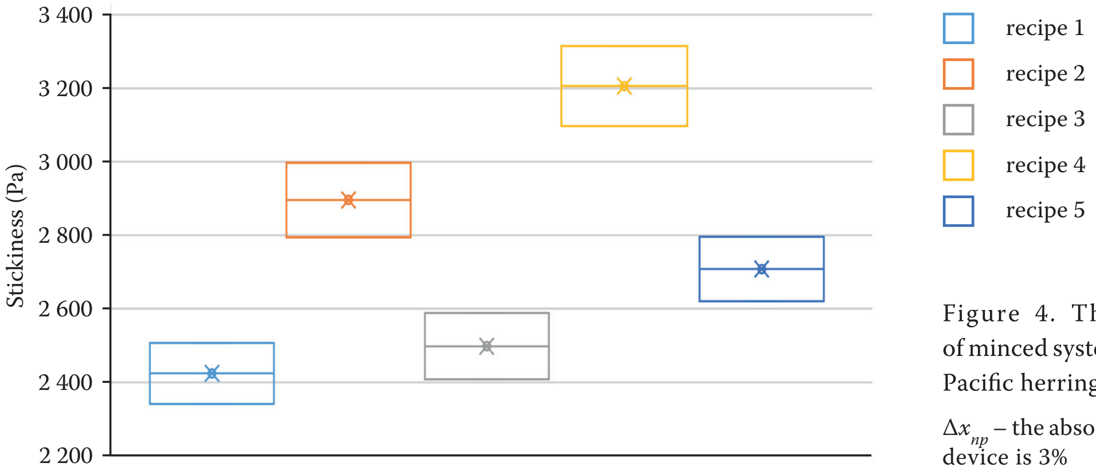

Figure 4. The stickiness of minced systems of pollock, Pacific herring, and seafood

Δx_{np} – the absolute error of the device is 3%

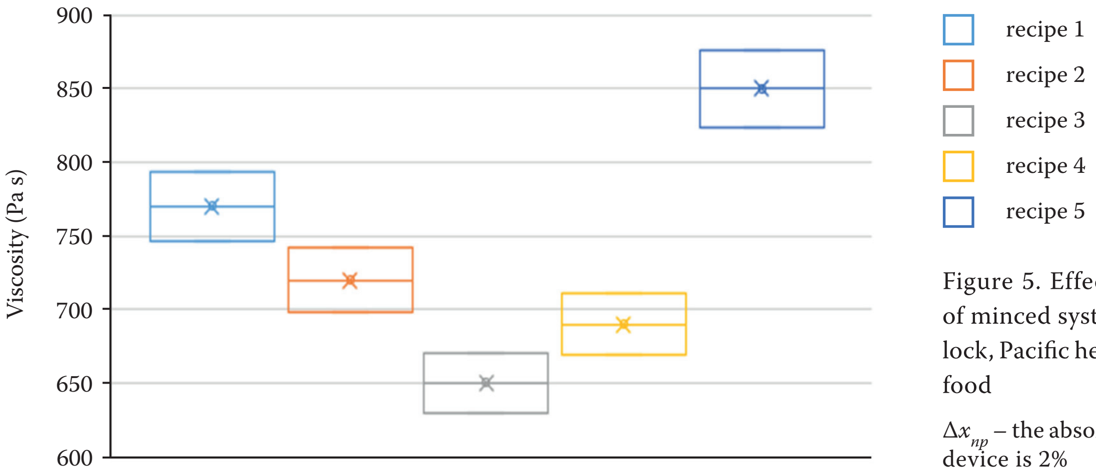

Figure 5. Effective viscosity of minced systems from pollock, Pacific herring, and seafood

Δx_{np} – the absolute error of the device is 2%

et al. 2014; Ucak and Gokoglu 2016). A decrease in the minced meat viscosity is observed with an increase in the fat content in the muscle tissue of fish (Ucak and Gokoglu 2016). This dependence was confirmed by our research. The minced system of pollock, Pacific herring, and mussels (recipe 3) had the lowest dynamic viscosity value of 650 Pa s and the highest fat content (3.7%), compared to other minced meat. The results of sensory evaluation of minced systems from pollock, Pacific herring, and seafood are given in Figure 6.

It was defined that the minced systems pre-processed with food additives had high sensory characteristics: a homogeneous consistency with small pieces of seafood. The colour of the minced meat varied from beige to dark brown. Minced meat was characterised by a dense and sticky texture, a pleasant smell of soy sauce, spices, and seafood. The highest sensory characteristics were observed in the minced system of pollock, shrimp, squid, and mussels (recipe 5).

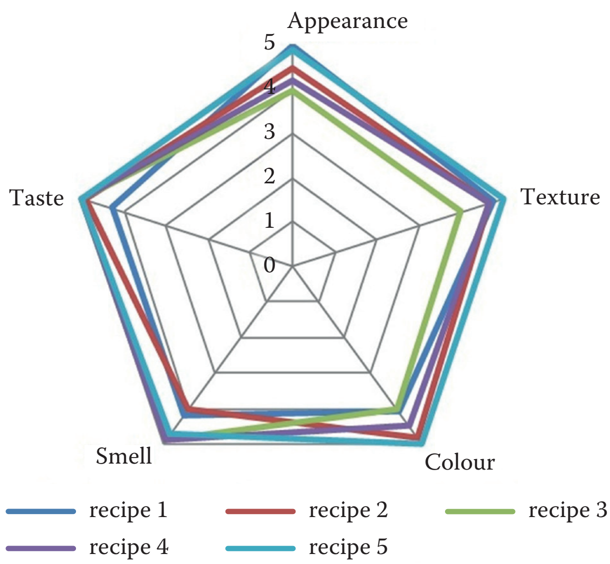

Figure 6. Profilograms of the organoleptic evaluation of minced systems from pollock, Pacific herring, and seafood

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CONCLUSION

The studied functional and technological properties of minced fish and seafood systems have shown the possibility of their use to obtain dried products. The addition of food additives to minced meat systems improves the rheological parameters, increases the organoleptic properties and energy value of the finished product. The proposed technology contributes to the expansion of the range of dried combined products using various types of raw food, and can be recommended for inclusion in production, including underutilised biologically valuable food fragments lost under the technological processing. We will continue studying in this direction which will make it possible to increase the coefficient of integrated use of raw materials and reduce the environmental stress from food production.

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