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The study of the nutritional and biological value of functional semi-finished fish products "fish balls"

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ABSTRACT

In the context of the problem of the organization of high-quality nutrition for consumers, the ways of its solution by expanding the range of products based on raw fish materials are considered. The necessity of creating combined semi-finished products with adequate substitution for plant components is justified, which allows increasing the amount of dietary fiber consumed and reducing the caloric content of the product, enriching minced fish with carbohydrates (polysaccharides and dietary fibers), amino acids, as well as macro- and microelements. Thus, a comparative analysis of the content of essential amino acids in the muscle tissue of fish in the inland waters of the Republic of Kazakhstan with some oceanic and marine fish showed that the content of amino acids such as leucine, lysine, threonine, phenylalanine is slightly higher. They are characterized by a high content of essential amino acids limiting the biological value, g/100 g of protein: lysine – 8.8-11.6; methionine – 2.1-3.1; tryptophan – 1.0-1.1. The data analysis shows that a higher pH value of fish meat corresponds to a higher elasticity value. The pH shift to the alkaline side of more than 7.5, although it promotes the release of myosin, reduces the elasticity of meat. In our study, we used minced fish from Carp, Pikeperch, Bream, and Pike. It was found that with the addition of 30% of the functional supplement of kelp, the moisture-retaining capacity of the fish semi-finished product was 48.6% and pH 6.67. With the addition of 30% of the functional pumpkin additive, the moisture-retaining capacity of the fish semi-finished product was 49.27% and pH 6.04. Developing semi-finished fish products with plant components makes it possible to obtain products of high biological value with a juicy consistency, which meets modern trends in healthy nutrition.

Keywords: balanced nutrition, fish, fish product, amino acid composition, moisture binding ability

INTRODUCTION

One of the ways to solve the problem of supplying the population with high-grade foods rich in proteins is to increase the production of fishery products, particularly commercial fish farming. Kazakhstan has a significant number of diverse ecologically clean reservoirs in which it is possible to produce environmentally friendly fish products (the total area of Kazakhstan's reservoirs, excluding the Caspian Sea, is about 5 million hectares). In the Republic of Kazakhstan, the export of fish products is among the important agricultural goods and ranks third in the ranking of the country's exports [1]. In the existing global trends in the production and turnover of food products, much attention is paid to developing and implementing preventive measures to ensure the safety of food products and the stable production of high-quality food products [2]. Fish product quality and safety are important for competitive advantage in the market [3]. Such stability is achieved only by applying a systematic approach that includes a detailed analysis and assessment of the nutritional value of finished fish products. Fish products are an important source of essential human nutrients: iodine and phosphorus, as well as protein and polyunsaturated fatty acids (eicosapentaenoic, docosahexaenoic, linoleic, linolenic, arachidonic) and fat-soluble vitamins. The nutritional value of fish products is high. Consumption of fish products by people with poor health

and different age groups, including children and, the elderly, pregnant women, is recommended. This connection shows the need to ensure guaranteed high-quality fish products [4].

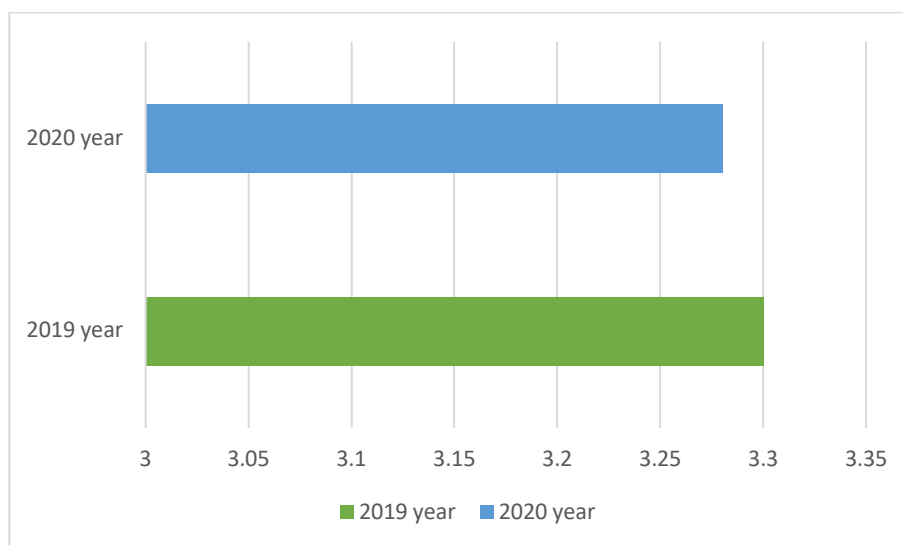


Figure 1 fish processing and production in Kazakhstan, USD.

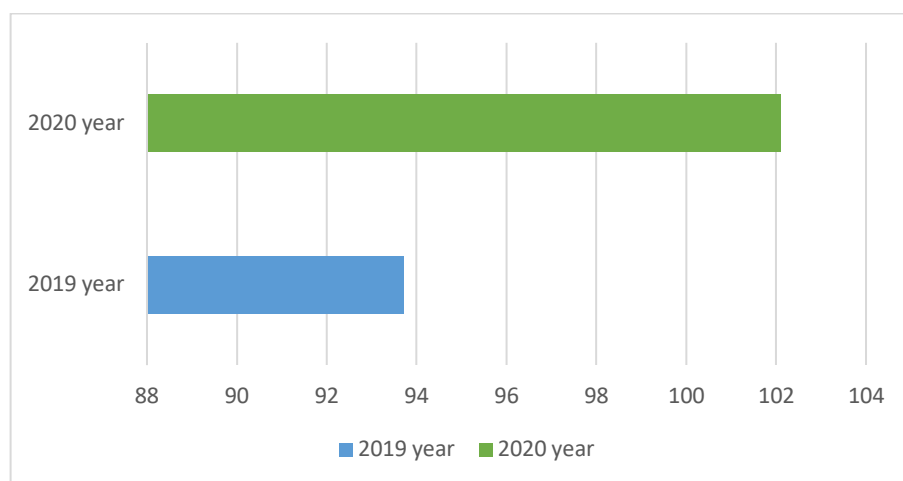


Figure 2 fish industrial production index in Kazakhstan, %.

Due to a large number of valuable nutritional nutrients (protein, fat, vitamins, etc.), fish products are susceptible to microbiological spoilage, leading not only to a rapid deterioration of organoleptic properties but also to the development of pathogenic microorganisms. In addition, the fish itself may contain dangerous parasites (varieties of trematodes, cestodes, scrapers, nematodes), toxins (tetrodotoxin, algotoxin, tyramine, putrescine, cadaverine, ichthyotoxin, etc.), heavy metals (primarily mercury) and pesticides. And in the process of production and storage, nitrosamines, benzopyrene, heavy metals, etc., may get into or form in fish products [5]. In recent decades, there has been a tendency in the fishing industry to increase the demand for fish products with a high degree of readiness [6]. First, this concerns the production of fish cutlets, which consumers actively buy in stores and public catering enterprises. The final heat treatment (heating, roasting, etc.) carried out outside the manufacturer (at home or catering establishments) does not imply the possibility of controlling the cooking modes of fish cutlets, which increases the risk of poisoning them in case of insufficient heat treatment. At the same time, quality claims will be addressed primarily to the manufacturer.

In this regard, scientific research aims to study semi-finished fish products' nutritional and biological value.

Scientific hypothesis

The development of the functional product from fish and vegetable raw materials can improve the nutritional value of the fish balls product. We expect an increase in the amino acid composition and mineral substances in the finished product after adding a functional supplement from kelp and pumpkin.

MATERIAL AND METHODOLOGY

Samples

Fish raw materials: carp, pike perch, bream, pike. Functional additives of vegetable origin: dried kelp and pumpkin.

Chemicals

All reagents used were of U.S.P. purity or higher. All solvents, including water, were used with the LC/MS label.

Instruments

The MOD MARS 6 microwave sample preparation system (MARS 6 Synthesis, CEM) was used for sample preparation. The amino acid composition was determined using high-performance liquid chromatography "Agilent-1200", with a separating column InfinityLab Poroshell 120 HILIC 1.9 microns.

Laboratory Methods

Laboratory studies of raw materials were carried out based on JSC "Almaty technological university" (Almaty, Kazakhstan). The total chemical composition: of moisture [9], fat [10], protein [11], ash [12], and amino acid composition [13] were determined.

Protein measurements were performed using the Kjeldahl method [43]. 5 g of homogeneous fillet with 20 mL of concentrated sulfuric acid and 8 g of catalysts were placed in a special container and then heated at 350 °C for 30 min. After mineralization, the sample was quantitatively transferred to a solution of NaOH at a concentration of 33%, sealed, and distilled off with steam. The resulting steam distillate was transferred to a container containing several drops of the Tashiro indicator. The titration was performed with a solution of 0.01 N sulfuric acid.

Total fat was measured by the Soxhlet method [8]. 4 g of the dried sample in a paper cartridge was placed in an extraction flask of a Soxhlet apparatus. Petroleum ether with a boiling point of 45 °C was used for the extraction. After multiple extractions, the weight of the test cartridge to constant weight was determined. The difference between the initial and final weight shows the percentage of fat.

Moisture was determined by the method of drying [7]. 5 g of the sample was placed in a container and dried for 1 hour at 150 °C.

Description of the Experiment

Sample preparation: The fish was cut after defrosting to study the mass composition.

Mass composition is the ratio of the mass of individual body parts and organs, expressed as a percentage of the mass of the whole fish. The study of mass composition is necessary for their rational use.

The cutting was carried out manually. When cutting fish, the heads, scales, skin, fins, insides, and black film were separated. Then fillets were cut from the spine while removing the spinal and rib bones. Each part was weighed, and its percentage ratio to the total weight of the fish was determined.

Number of samples analyzed: we analyzed 12 samples.

Number of repeated analyses: All measurements of instrument readings were performed two times.

Number of experiment replication: The number of repetitions of each experiment to determine one value was two times.

Design of the experiment: At the beginning of the experiment, we determined the content of moisture, protein, fat, ash, salt, and acidity. The amino acid composition, the water-binding ability of minced fish in combination with vegetable ingredients, and the mineral composition were studied. Based on the data obtained, determine the recipe for a semi-finished product from minced fish.

Statistical Analysis

Microsoft Excel and Statistica 15 produced the statistical data analysis. All experiments were carried out in triplicate and the results reported are the results of those replicate determinations with standard deviations. The Student t-test was used for the statistical analysis of the obtained results. Data are presented as mean \pm standard error of the mean (SEM). The smallest acceptable difference for probes from the one sample was pointed at 5%. Probes with more differences were not considered.

RESULTS AND DISCUSSION

Analysis of the data on the mass composition of fish shows that the relative mass of pure meat (without skin) in the studied fish is 35-40% of the total weight. The terrain coefficient, defined as the ratio of the pulp part to other parts, is 0.58 for carp, 0.60 for walleye, 0.62 for bream, and 0.62 for pike. The averaged data on the mass composition of particle fish are presented in Table 1.

Table 1 Mass composition of fish, %.

Fish	Muscle tissue	Heads	Entrails, skin, scales, bones, fins	Losses
Carp	36.90 ±5.28 ^c	20.13 ±2.93 ^b	37.34 ±4.73 ^c	5.63 ±2.03 ^a
Pike perch	37.39 ±4.17 ^c	23.68 ±0.05 ^b	34.98 ±3.95 ^d	4.45 ±1.40 ^a
Bream	38.10 ±4.15 ^d	24.12 ±2.04 ^b	30.63 ±0.79 ^c	7.15 ±0.29 ^a
Pike	38.20 ±3.12 ^c	20.06 ±1.02 ^b	38.19 ±4.03 ^c	3.01 ±1.32 ^a

Note: ^{a-d} means within the same row with different uppercase letters differing significantly among different meat samples ($p < 0.05$). All values are expressed as the mean ±SD (standard deviation).

In the production of semi-finished fish products, muscle tissue is of the greatest interest. A complex chemical composition characterizes muscle tissue. It includes many chemicals, among which water, proteins, lipids, and minerals predominate. The content of the main components varies quite widely depending on many factors.

The chemical composition was evaluated based on the average values obtained by analyzing average fish samples taken according to the method

The average chemical composition of muscle tissue is shown in Table 2.

Table 2 General chemical composition of fish muscle tissue, %.

Indicators	Bream	Perch
Water	75.29 ±1.80 ^a	78.50 ±0.70 ^a
Protein	17.5 ±0.12 ^a	18.8 ±0.10 ^a
Fat	4.80 ±1.30 ^b	0.88 ±0.35 ^a
Mineral substances	1.25 ±0.42 ^a	1.13 ±0.24 ^a

Note: ^{a-b} means within the same row with different uppercase letters differing significantly among different meat samples ($p < 0.05$). All values are expressed as the mean ±SD (standard deviation).

The results of the analysis of the chemical composition of fish showed that the main components of muscle tissue - water, fat, and protein - are quantitatively dependent on each other. Fish with a high-fat content have less water and protein. The criteria protein/moisture, fat/protein, and fat/moisture are used to characterise the muscle tissue of fish. We calculated the above criteria based on the total chemical composition data (Table 3).

Table 3 Criteria for evaluating the qualitative indicators of the muscle tissue of particle fish, %.

Fish	Criteria		
	protein/moisture	fat/moisture	fat/protein
Carp	0.23 ±0.12 ^b	0.06 ±0.15 ^a	0.27 ±0.12 ^b
Pike perch	0.24 ±0.30 ^b	0.01 ±0.12 ^a	0.03 ±0.30 ^a
Bream	0.21 ±0.15 ^b	0.08 ±0.15 ^a	0.37 ±0.12 ^c
Pike	0.23 ±0.12 ^b	0.01 ±0.12 ^a	0.04 ±0.12 ^a

Note: ^{a-c} means within the same row with different uppercase letters differing significantly among different meat samples ($p < 0.05$). All values are expressed as the mean ±SD (standard deviation).

For a complete characterization of the biological value, the amino acid composition of the muscle tissue of fish was studied (Table 4). Analysis of the amino acid composition data indicates a rich set of essential amino acids in the proteins of the studied fish. A comparative analysis of the content of essential amino acids in the muscle tissue of fish in inland waters of the Republic of Kazakhstan with some oceanic and marine fish showed that the content of amino acids such as leucine, lysine, threonine, phenylalanine is slightly higher in them (Table 4). They are characterized by a high content of essential amino acids limiting the biological value, g/100 g of protein: lysine 8.8-11.6; methionine 2.1-3.1; tryptophan 1.0-1.1.

Table 4 Amino acid composition of fish meat proteins, g/100 g of protein Amino Acids.

	Fish			
	carp	walleye	pike	bream
Valin	6.6 ±0.591 ^b	5.3 ±0.712 ^a	5.3 ±0.823 ^a	6.4 ±0.823 ^b
Isoleucine	5.1 ±0.913 ^a	5.1 ±0.908 ^a	5.1 ±0.567 ^a	5.0 ±0.765 ^a
Leucine	9.2 ±0.358 ^b	7.6 ±0.343 ^a	7.6 ±0.485 ^a	9.1 ±0.498 ^b
Lysine	11.6 ±0.421 ^b	8.8 ±0.409 ^a	8.8 ±0.498 ^a	11.6 ±0.564 ^b
Methionine	3.3 ±0.448 ^b	2.1 ±0.401 ^a	2.1 ±0.713 ^a	3.1 ±0.583 ^b
Threonine	5.9 ±0.582 ^b	4.3 ±0.540 ^a	4.3 ±0.481 ^a	5.9 ±0.387 ^b
Tryptophan	1.1 ±0.314 ^a	1.0 ±0.293 ^a	1.0 ±0.794 ^a	1.1 ±0.987 ^a
Phenylalanine	5.1 ±0.776 ^b	3.8 ±0.831 ^a	3.8 ±0.298 ^a	5.0 ±0.639 ^b
Total essential amino acids	47.9 ±0.582 ^b	38.0 ±0.656 ^a	38.0 ±0.743 ^a	47.2 ±0.351 ^b
Alanine	6.9 ±0.337 ^a	7.1 ±0.593 ^a	6.6 ±0.458 ^a	6.7 ±0.769 ^a
Arginine	6.0 ±0.555 ^b	5.6 ±0.386 ^a	5.6 ±0.489 ^a	5.9 ±0.475 ^b
Aspartic acid	10.9 ±0.812 ^b	8.8 ±0.694 ^a	8.8 ±0.845 ^a	10.5 ±0.867 ^b
Histidine	2.2 ±0.587 ^a	2.2 ±0.160 ^a	3.6 ±0.645 ^b	2.2 ±0.476 ^a
Glycine	3.7 ±0.912 ^a	5.5 ±0.293 ^b	5.5 ±0.948 ^b	3.8 ±0.398 ^a
Glutamic acid	16.6 ±0.811 ^b	12.8 ±0.656 ^a	12.8 ±0.526 ^a	16.6 ±0.374 ^b
Proline	3.1 ±0.448 ^a	6.1 ±0.912 ^b	6.1 ±0.185 ^b	3.1 ±0.189 ^a
Serine	5.0 ±0.451 ^b	3.1 ±0.871 ^a	3.1 ±0.367 ^a	5.0 ±0.856 ^b
Tyrosine	3.8 ±0.358 ^c	2.8 ±0.784 ^b	2.4 ±0.847 ^a	3.7 ±0.769 ^c
Cystine	-	1.5 ±0.654 ^a	1.5 ±0.657 ^a	-
Oxyproline	-	-	-	-
Total interchangeable amino acids	58.2 ±0.324 ^a	55.5 ±0.293 ^a	56.0 ±0.412 ^a	57.5 ±0.385 ^a

Note: ^{a-c} means within the same row with different uppercase letters differing significantly among different meat samples ($p < 0.05$). All values are expressed as the mean ±SD (standard deviation).

For a reasonable combination of minced fish from various types of fish, studies of the functional and technological properties of minced meat are carried out.

During experimental studies, the elasticity of fish raw materials was studied, which can be judged by the content of myosin and the pH value. The data analysis shows that a higher pH value of fish meat corresponds to a higher elasticity value. The pH shift to the alkaline side of more than 7.5, although it promotes the release of myosin, reduces the elasticity of meat. Perch has the best elasticity (3.32-4.12). Changes in the elasticity of the same species of fish are probably due to the following factors: the age of the fish, the season and depth of their habitat, the shelf life, the method of processing raw materials. Fish meat's pH value also affects its moisture binding ability, which increases with increasing pH.

Based on the results of the analysis of the literature data, the possibility and expediency of expanding the range of minced fish products with vegetable raw materials have been established. Scientists have researched the combination of fish and duck meat to improve the nutritional value and the technological properties of finished products [9]. The theory of balanced nutrition allows us to study and justify the nutritional and biological value of many products based on the study of their chemical analysis [10]. studies of the chemical composition of human food products allow us to understand values and categories. Thus, the nutritional value of a product is the ratio of the product's chemical composition to match the basic form of a balanced diet [11]. The functional properties of the finished product directly depend on the chemical composition of the raw materials. fats, proteins, carbohydrates in the composition of food products characterize the sensory qualities of the finished product [12]. The compatibility of the components of the finished product and the compatibility of the chemical composition of all components inside the product is a key point in developing new food products [13]. The most important and initial work in developing new food products is studying raw materials' nutritional value and chemical composition [14]. The table analysis shows that the freshwater fish studied belongs to low-fat protein raw materials. The crude protein content in the carp muscles was 18.60-18.78%, depending on the catch season. The protein concentration in the carp meat was slightly lower and amounted to 17.60-17.70%. High levels of protein in muscle in both marine and freshwater aquaculture have been identified by several researchers [15]. Scientists from different countries are researching the chemical analysis of fish raw materials. So, some results confirm the increased influence of fish protein in the human diet [16], [17], [18]. A comparative analysis of fish meat with poultry meat showed that the ratio of protein and fat is almost the same [19], [20]. Studies have also been conducted to replace fish meat with poultry meat. studies have shown that this combination positively affects the

final product [21], [22]. The muscle tissue's moisture and protein content determine the finished product's consistency, taste, and yield. The moisture content also significantly impacts the structure of functional groups of protein molecules, their stabilization and spatial configuration, and thus the functional and technological properties of the meat system as a whole [23], [24]. Calculating the coefficients of chemical composition and food saturation gives an understanding of the saturation of the finished product [25]. complex heterogeneous food systems include minced meat, especially fish meat. The technological properties of a product directly depend on the chemical composition of the carcass [26]. Protein and its properties in finished food products largely depend on the addition of sodium chloride to it. The method of salting and its quantity directly affect the structural and mechanical characteristics of food products [27]. The muscle tissue of fish and the ability to bind moisture depends on several indicators, namely temperature, acidity, and degree of dispersion [28]. The minced fish's size and the grinding grate's diameter are extremely important in choosing optimal indicators of immobilized moisture [29]. The moisture binding ability takes an active part in maintaining the freshness of fish. it also greatly impacts the output and quality of finished products [30]. According to some scientists, an increase in the moisture binding ability increases the adhesive qualities of minced fish, the elasticity of the resulting minced fish, the shear stress decreases, and the functional properties improve [31]. Introducing up to 3% salt into minced meat improves the rheological characteristics of minced meat, increasing the solubility of proteins [32]. Some scientists say adding less than 1% of table salt to minced meat is not recommended. This can damage raw materials and, subsequently, finished products [33]. Functional groups of proteins have properties to attract free water, increasing hydration. and as a consequence, the moisture-binding ability. This is due to the addition of table salt [34]. The higher emulsifying ability of the muscle tissue of the crucian carp is due to the values of the coefficients C_w and PWF , as well as the content of bound moisture. The EC and SE of minced meat are higher when $NaCl$ is added. The values of these indicators are consistent with the indicators of WHC and WBC of minced fish. They are due to the increased content of water-soluble and salt-soluble fractions of muscle tissue proteins of hydrobionts [35]. For this reason, only mobile and flexible protein macromolecules can form adsorption layers at the interface of the two phases and form a helical gel structure in a continuous phase [36]. According to Wang [37], the emulsifying ability of minced poultry meat is 75%. The stability of the emulsion is about 70%, which, when combined with multicomponent functional mixtures based on animal proteins [38], [39], [40], [41], [42], will effectively develop meat products with a combined composition of raw materials.

Introducing a vegetable component into minced fish will make it possible to obtain a new product – fish semi-finished products with functional properties. Experimental production of fish semi-finished products, "fish balls" for functional purposes was carried out in the educational and scientific center for meat processing of JSC "Almaty Technological University". Minced fish from pike perch, bream, and roach were the main raw materials. As functional ingredients, dried kelp and pumpkin. To carry out the planned studies, 10% to 30% of kelp and crushed pumpkin were added to the minced meat instead of minced fish. Physico-chemical and functional-technological indicators evaluated the resulting combined minced meat, in particular, the moisture binding ability and pH of minced meat were determined compared to the control. Minced fish without additives was used as a control. When vegetable additives are added to minced fish, the chemical composition of minced fish is replenished with dietary fibers, as evidenced by an increase in fiber content (Table 5, Figure 3).

Table 5 Physico-chemical parameters of the fish semi-finished product.

Sample	Mass fraction, %			Fiber content, %
	fat	protein	moisture	
Control sample	25.21 ±0.02 ^c	9.62 ±0.01 ^b	46.91 ±0.01 ^d	2.21 ±0.01 ^a
Prototype with 10% kelp replacement	24.75 ±0.05 ^c	9.76 ±0.02 ^b	54.10 ±0.02 ^d	3.14 ±0.01 ^a
Prototype with 30% kelp replacement	33.97 ±0.05 ^c	9.84 ±0.02 ^b	56.09 ±0.02 ^d	5.44 ±0.01 ^a
Prototype with 10% pumpkin replacement	23.72 ±0.05 ^c	9.72 ±0.02 ^b	46.33 ±0.01 ^d	2.92 ±0.01 ^a
Prototype with 30% pumpkin replacement	30.46 ±0.05 ^c	9.33 ±0.02 ^b	53.72 ±0.01 ^d	4.31 ±0.01 ^a

Note: ^{a-d} means within the same row with different uppercase letters differing significantly among different meat samples ($p < 0.05$). All values are expressed as the mean ±SD (standard deviation).

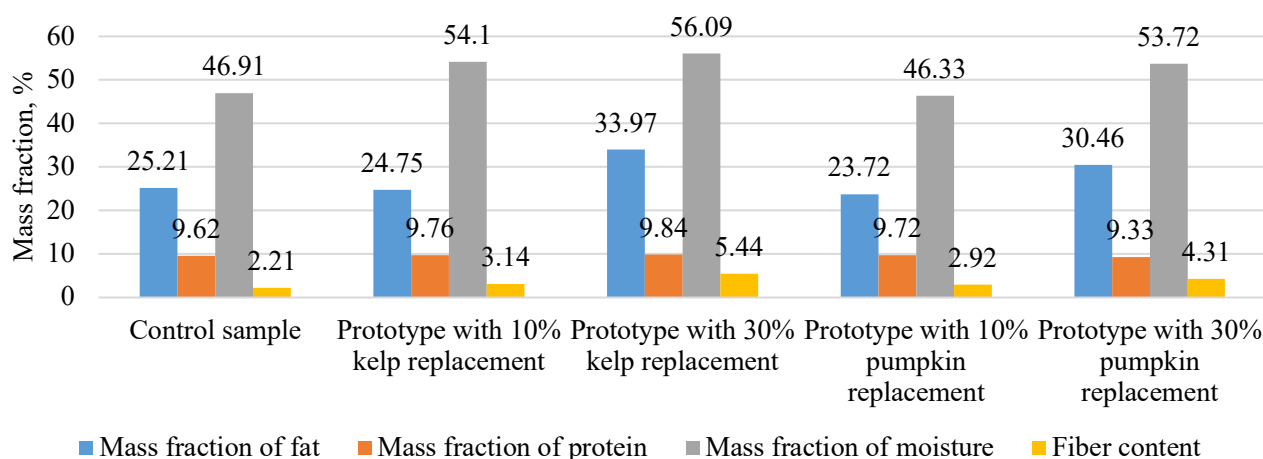


Figure 3 Dynamics of changes in physical and chemical parameters of the fish semi-finished product.

As a result of the study of functional and technological parameters of minced fish, the dependence of moisture binding ability and pH on the amount of application of functional ingredients was established. The ability of minced meat to bind and retain water and its stability during heat treatment varies depending on the morphological composition, pH, protein, fat, moisture, and dietary fiber content in minced meat and their ratio. The content of muscle and connective tissue in raw materials and dietary fiber in minced meat significantly ($p < 0.05$) affect (the moisture binding ability of) the functional properties of minced meat (Table 6).

Table 6 Functional and technological indicators of the fish semi-finished product.

Indicators	Control sample	Prototype			
		kelp		pumpkin	
		10%	30%	10%	30%
Moisture binding ability, %	49.27 ± 0.59 ^a	59.54 ± 0.65 ^b	62.48 ± 1.19 ^c	50.66 ± 1.06 ^a	59.84 ± 1.02 ^b
Moisture-holding capacity, %	45.51 ± 0.96 ^a	46.72 ± 0.89 ^a	48.60 ± 0.73 ^c	47.34 ± 0.96 ^b	49.27 ± 0.84 ^d
Fat-holding capacity, %	69.06 ± 1.04 ^d	50.82 ± 0.76 ^b	40.68 ± 0.85 ^a	60.68 ± 1.15 ^c	50.73 ± 0.91 ^b
pH	6.7 ± 0.1 ^c	6.66 ± 0.01 ^b	6.67 ± 0.01 ^b	6.24 ± 0.01 ^a	6.04 ± 0.01 ^a

Note: ^{a-d} means within the same row with different uppercase letters differing significantly among different meat samples ($p < 0.05$). All values are expressed as the mean ± SD (standard deviation).

The maximum moisture binding ability and pH are noted when functional ingredients are added to minced fish in 30%; moisture binding ability was 48.6% and pH 6.67 when replaced with kelp and 49.27 and 6.04, respectively, when replaced with pumpkin. The pH increases until a certain maximum value is reached, at which the maximum protein solubility is observed, affecting the hydrophilicity of fish proteins. Therefore, it causes an increase in the moisture binding ability of the combined stuffing system. The increase in these indicators is associated with introducing carbohydrates and dietary fibers contained in plant components into minced meat and their participation in forming protein-polysaccharide complexes with increased emulsifying and stabilizing ability and influencing the stabilization of the structure and the content of strongly bound moisture. Accordingly, combined minced meat's increased moisture binding ability is also associated with swelling processes. The effect of introducing vegetable additives on the mineral content and amino acid composition of the fish semi-finished product was also studied (Table 7).

After analyzing the data presented in Table 7, it can be concluded that introducing plant components increases the product's nutritional value. In samples 1 and 2, due to the introduction of kelp, the mineral composition, and amino acid composition content increase. In the samples, an increase in iron content, a vital trace element for the human body, is noted.

Table 7 Dynamics of changes in the content of minerals, and amino acid composition of fish semi-finished products, depending on the proportion of vegetable additives.

Indicators	Control sample	Prototype			
		Prototype with 10% kelp replacement	Prototype with 30% kelp replacement	Prototype with 10% pumpkin replacement	Prototype with 30% pumpkin replacement
Mineral elements, mg/100 g					
Potassium	281.25 ±4.22 ^a	-	487.88 ±7.32 ^d	312.55 ±5.99 ^c	299.88 ±4.48 ^b
Magnesium	35.14 ±0.74 ^b	-	75.60 ±1.53 ^c	32.83 ±0.49 ^a	29.98 ±0.31 ^a
Iron	0.58 ±0.005 ^a	1.81 ±0.03 ^b	5.21 ±0.06 ^c	0.60 ±0.008 ^a	0.74 ±0.01 ^a
Sodium	55.32 ±0.61 ^b	107.43 ±1.61 ^c	194.72 ±4.09 ^d	49.79 ±0.55 ^a	47.12 ±0.46 ^a
Calcium	53.75 ±0.59 ^c	57.85 ±0.98 ^d	49.63 ±0.55 ^b	50.86 ±0.76 ^b	43.95 ±0.48 ^a
Zinc	1.2 ±0.01 ^b	1.43 ±0.03 ^c	1.2 ±0.01 ^b	1.11 ±0.01 ^b	0.91 ±0.02 ^a
Iodine	0.038 ±0.0003 ^a	0.188 ±0.012 ^b	0.78 ±0.015 ^c	0.034 ±0.0007 ^a	0.028 ±0.0005 ^a
Phosphorus	267.22 ±2.94 ^c	302.35 ±4.54 ^d	323.55 ±14.24 ^c	244.90 ±5.14 ^b	200.25 ±3.60 ^a
Mass fraction of amino acids, %					
Arginine	0.44 ±0.18 ^a	0.49 ±0.20 ^b	0.54 ±0.22 ^c	0.60 ±0.24 ^d	0.46 ±0.18 ^a
Lizine	0.50 ±0.17 ^d	0.49 ±0.17 ^d	0.35 ±0.12 ^a	0.45 ±0.15 ^c	0.40 ±0.14 ^b
Tyrosine	0.14 ±0.04 ^a	0.11 ±0.03 ^a	0.17 ±0.05 ^a	0.13 ±0.04 ^a	0.16 ±0.05 ^a
Phenylalanine	0.26 ±0.08 ^a	0.23 ±0.07 ^a	0.17 ±0.05 ^a	0.20 ±0.06 ^a	0.22 ±0.06 ^a
Histidine	0.07 ±0.03 ^a	0.10 ±0.05 ^a	0.13 ±0.06 ^a	0.20 ±0.10 ^b	0.19 ±0.09 ^a
Leucine+isoleucine	0.39 ±0.10 ^c	0.38 ±0.10 ^c	0.24 ±0.06 ^a	0.32 ±0.08 ^b	0.33 ±0.09 ^b
Methionine	0.21 ±0.07 ^b	0.20 ±0.07 ^b	0.15 ±0.05 ^a	0.20 ±0.07 ^b	0.17 ±0.06 ^a
Valine	0.41 ±0.16 ^c	0.39 ±0.16 ^d	0.22 ±0.09 ^a	0.32 ±0.13 ^b	0.36 ±0.14 ^c
Proline	0.28 ±0.07 ^b	0.30 ±0.08 ^c	0.15 ±0.04 ^a	0.20 ±0.05 ^b	0.27 ±0.07 ^b
Treoline	0.33 ±0.13 ^c	0.32 ±0.13 ^c	0.15 ±0.06 ^a	0.22 ±0.09 ^b	0.26 ±0.11 ^b
Serine	0.24 ±0.06 ^b	0.28 ±0.07 ^c	0.16 ±0.04 ^a	0.22 ±0.06 ^b	0.23 ±0.06 ^b
Alanine	0.42 ±0.11 ^c	0.45 ±0.12 ^c	0.26 ±0.07 ^a	0.37 ±0.10 ^b	0.40 ±0.10 ^c
Glycine	0.44 ±0.15 ^c	0.39 ±0.13 ^b	0.20 ±0.07 ^a	0.27 ±0.09 ^a	0.43 ±0.15 ^c

Note: ^{a-e} means within the same row with different uppercase letters differing significantly among different meat samples ($p < 0.05$). All values are expressed as the mean ±SD (standard deviation).



Figure 4 Semi-finished fish products "fish balls".

CONCLUSION

Thus, a comparative analysis of the content of essential amino acids in the muscle tissue of fish in the inland waters of the Republic of Kazakhstan with some oceanic and marine fish showed that the content of amino acids such as leucine, lysine, threonine, phenylalanine is slightly higher. They are characterized by a high content of essential amino acids limiting the biological value, g/100 g of protein: lysine 8.8-11.6; methionine 2.1-3.1; tryptophan 1.0-1.1. The data analysis shows that a higher pH value of fish meat corresponds to a higher elasticity value. The pH shift to the alkaline side of more than 7.5, although it promotes the release of myosin, reduces the elasticity of meat. The maximum moisture binding ability and pH are noted when functional ingredients are added to minced fish in an amount of 30%. Moisture binding ability was 48.6% and pH 6.67 when replaced with kelp and 49.27 and 6.04, respectively, when replaced with pumpkin. The development of semi-finished fish products with the use of plant components makes it possible to obtain products of high biological value with a juicy consistency, which meets modern trends in healthy nutrition.

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