The influence of plant components and food additives on the nutritional and biological value of fish chips from low-value pond fish

Zhibek Maatkerimova[1*], *Svetlana* Tarasova[1], *Elmira* Kaparova[1], and *Lazzat* Primbetova[1]

[1]Kyrgyz National Agrarian University named after K.I. Skryabin, Bishkek, Kyrgyzstan

Abstract. This paper examines research findings on the development of a fish chip recipe with added plant-based ingredients. The use of low-value fish species in the recipe was studied to increase the nutritional and biological value of the finished product. The ratios of recipe components were determined to create a product enriched with macro- and microelements and dietary fiber. The functional properties of fish chips were determined to improve the nutritional quality of various age groups, including schoolchildren, the elderly, and athletes. The studies confirmed the safety of the chips, in accordance with the requirements of TR CU 040/2016 "On the Safety of Fish and Fish Products," as well as improved nutritional and biological value. It was found that the advanced processing of low-value fish species, including silver carp, increases production profitability by at least 16%.

1 Introduction

Low-value pond fish species are well represented on the Kyrgyz fish market, but they are not widely popular among consumers. Despite their relative affordability - approximately three times cheaper (350 som) than rainbow trout (1,000 som) - local pond fish are not in demand due to the presence of small bones and waste, such as the head. The head of the silver carp accounts for 20 to 26% of the total fish weight. According to some authors, the meat yield of silver carp is 36.6%, bone residue 14.7%, head 24.3%, viscera 9.3%, fins 5.8%, and scales 3.6% [1].

The taste of silver carp meat does not differ significantly from that of more valuable fish species. According to some researchers, silver carp meat is characterized by high protein content (over 15%) and a white color due to the absence of myoglobin. In terms of fat content, it is classified as medium-fat (more than 5.6%). Silver carp meat has a balanced amino acid composition and is also rich in vitamins and minerals. Of the minerals, silver carp meat contains calcium (41 mg / 100 g), iron (1.24 mg), magnesium (29 mg), phosphorus (415 mg), potassium (333 mg), zinc (1.48 mg), copper (0.057 mg), manganese (0.042 mg) and selenium (12.6 µg / 100 g). In terms of taste, silver carp meat is moderately fatty, juicy, tender and tasty. It is a valuable dietary food. Silver carp meat is useful for the elderly, as a source of deficient essential amino acids tryptophan, lysine and methionine.

* Corresponding author: maatkerimova.zhibek@mail.ru

Eating silver carp meat is recommended for the prevention of atherosclerosis, osteoporosis, and normalization of the nervous system [1].

Kyrgyzstan has seen an annual increase in fish catches. In 2024, fish production exceeded 27,000 tons (Figure 1). According to the Ministry of Economy, fish farming productivity has increased significantly thanks to the introduction of a zero VAT rate on trout feed [2].

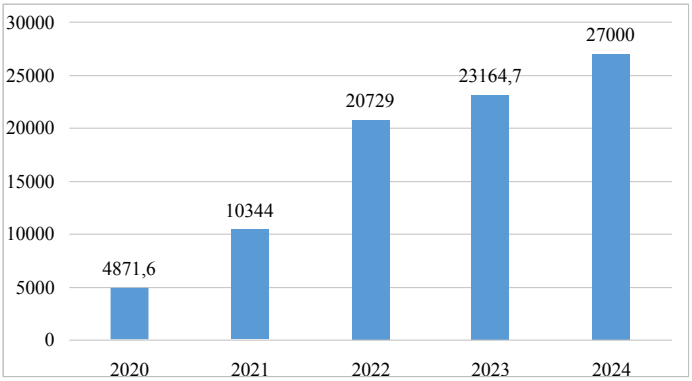

Figure 1. Gross fish farming output for 2020-2024, tons.

Freshwater fish account for 30.8% of the total fisheries production. FAO research data indicate the low popularity of freshwater fish, most often due to a lack of knowledge about processing techniques and the creation of new products from low-value fish (Table 1 and Figure 2) [3].

Table 1. Species composition of aquaculture in Kyrgyzstan, 2022 (in quantitative terms)

Fish Species	Quantity, tons
Rainbow Trout	14325
Silver Carp	2408
Common Carp	2123
Grass Amur	1774
Other Freshwater Fish	50
Whitefish	20
Sturgeon	9

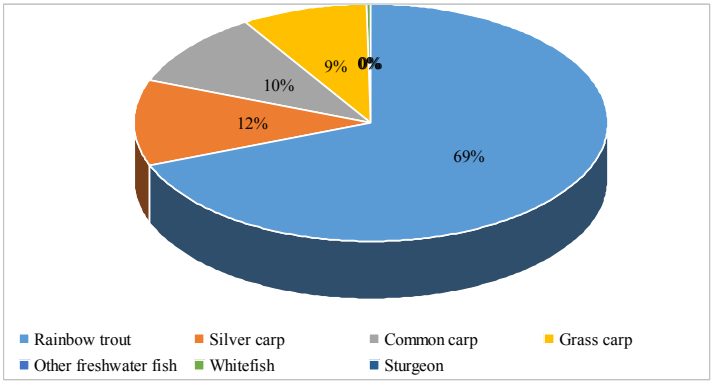

Figure 2. Share of species composition of caught fish, percentage.

As shown in Table 1 and Figure 2, rainbow trout accounts for over 69% of the total fish production. Silver carp accounts for 12% of the total production of the main aquaculture species.

Silver carp are characterized by a rapid growth rate and are easy to maintain in the wild. Unlike trout, silver carp do not require special feed and thrive on natural food sources. Silver carp farming requires clean, large, deep, moderate-temperature waters. Silver carp reach their maximum length gain at two years of age, with growth tapering off in subsequent years [4]. Silver carp meat is suitable for all types of fish processing.

Currently, a wide range of fish products is available in stores: salted, dried, cold-smoked, as well as canned and frozen semi-finished products. However, Kyrgyzstan's per capita protein consumption is only 90.2 g/day, and fish and seafood account for only 0.3% of the total daily protein intake. This low figure is explained by the annual population growth. Per capita fish and seafood consumption in Kyrgyzstan in 2019 was 0.9 kg, the second lowest in Central Asia and the Caucasus. However, due to the development of aquaculture and the creation of favorable production conditions, fish and seafood consumption has reached 3.0 kg [1].

To further develop the fishing industry and implement proposals for the complete processing of raw materials, it is necessary to develop a technology for the integrated use of raw materials to create a range of products that meet consumer demand and meet healthy eating standards.

Fish chips were chosen as the subject of this study because they are in high demand among both adults and children. Chips made from plant-based ingredients with added flavors are currently quite popular. Fish chips are easy to prepare and don't require expensive or complex equipment. They can be prepared using any kitchen equipment, and the finished product can be processed on a farm. Fish chips are a new product on the fish market, with existing technological developments in this range of fish products. Developing technology and recipes for fish chips is relevant because they are an innovative product, reflecting the healthy eating trend and the demand for convenient snacks with high added value. Fish chips combine the health benefits of fish (protein, omega-3 fatty acids) with the convenience of being consumed on-the-go or as a standalone snack. The production of such a food product will allow the use of various types of fish, including less valuable ones, in processing. The development of fish chips is relevant due to the popularity of snacks among fish consumers. Fish chips provide an additional source of animal protein and omega-3 fatty acids, making them an attractive choice for health-conscious consumers. Fish chips are a new and original product on the market that has the potential to attract consumer attention and carve out a niche in the snack market.

The development of fish chips allows for the use of a variety of fish species, including those underutilized in traditional cuisine, such as small fish or fillet processing scraps. The development of fish chips has encouraged farmers to cultivate carp species on their farms as a raw material for producing fish products with increased nutritional and biological value. Ultimately, the technology for producing chips from low-value fish contributes to increased economic efficiency in fish production and reduced waste.

Research objectives to validate a fish chip recipe using plant-based ingredients and food additives to produce a nutritionally enhanced product from low-value pond fish.

2 Research materials and methods

Laboratory analysis and comparison of physicochemical parameters of fish products. Methods for determining the pH of minced fish. GOST ISO 2917-2017 Meat and meat products. pH determination. Reference method. The methods for determining safety

parameters were conducted in accordance with Technical Regulation CU 021/2011 "On Food Safety" and TR CU 040/2016 "On the Safety of Fish and Fish Products."

3 Research results

An improved fish chip recipe was developed using a combination of fish and plant-based ingredients (Table 2). Pumpkin flour, curry seasoning, and sodium lactate were proposed as additional plant-based ingredients.

Table 2. Fish chips recipe.

Name of ingredients	Mass fraction, %	
	Control	Experienced
Silver Carp Fillet	83.8±87.5	67.5
Fish Broth	0.84±0.87	5.1
Potato Starch	1.68±2	5.81
Corn Flour	8.0±0.27	8.45
Pumpkin Flour	-	7.82
Sodium Pyrophosphate	0.25±0.26	0.03
Curry Seasoning	-	0.2
Salt	2.3±2.45	3.45
Shrimp Flavoring	0.17	1.5
Titanium Dioxide	0.08±0.09	0.09
Sodium Lactate	-	3
Total	100.0	100.0

Pumpkin seeds are also considered a valuable source of a complex of functional ingredients. Pumpkin flour is a dry powder obtained by processing pumpkin seeds. Both unhulled and hulled seeds are used to produce flour. Curry is a spice widely used in South Asian cuisine, particularly Indian, as well as European and Central Asian cuisine. It imparts a distinctive aroma, flavor, and color to dishes. Sodium lactate E325 is a food additive that can extend the shelf life of food products and improve their organoleptic properties. The ratios of the recipe ingredients are determined based on patent analysis and experimental results.

After the minced meat was prepared, a pH test was carried out, the value of which indicates the freshness (quality) of the raw material (Figure 3).

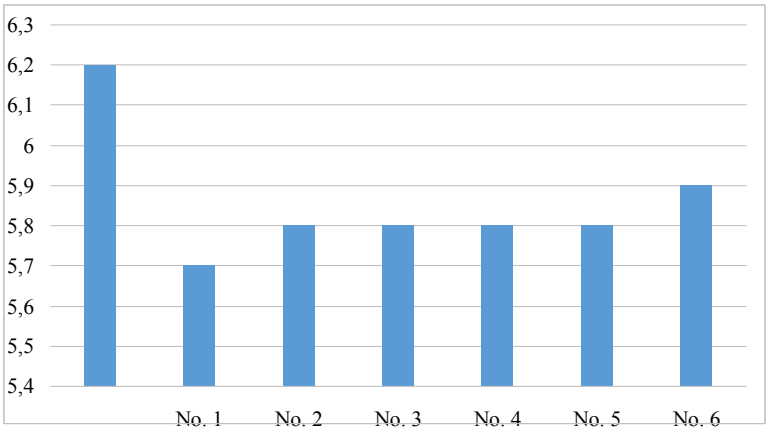

Figure 3. Determination of pH of minced meat.

The pH values of the test samples ranged from 5.7 to 5.9, which is lower than the control sample (6.2). This indicates a change in the product's acidity as a result of changes in the recipe or production technology. Sample No. 1 had the lowest pH (5.7), while sample No. 6 had the highest pH (5.9). This change in pH is due to the effect of food additives, particularly sodium pyrophosphate, on the physicochemical properties. This decrease in pH compared to the control may indicate an increase in acidity, which potentially affects the taste, microbiological stability, and shelf life of the product.

The organoleptic properties of fish chips are characterized by their shape and size: flat and round, like potato chips. Color: golden or light brown, resulting from frying. Texture: crispy, moderately dense. Surface: slightly rough. Taste and aroma: pleasant and delicate, with distinct fish notes. To determine the mineral composition of the control and test samples, studies were conducted in an accredited laboratory of KyrgyzstanDart (protocols No. 921-III(1)). Table 3 shows the results of the analysis of the mineral content of fish chips and calculations based on the daily requirement in percentage.

Table 3. Content of mineral elements in fish chips, mg/100 grams.

Name of elements	Product name		Recommended intake, mg/day	Satisfaction of daily requirements in percentage
	Fish chips No. 1 control	Fish chips No. 2 experienced		
Ca	32.2	41.5	1000	4.15
Na	1806.7	1922.3	1300	147.8
K	594.4	692.3	3500	19.8
Mn	0.064	0.075	2	3.7
Zn	1.32	2.22	12	18.3
Se	0.34	0.25	55-70	0.45-0.36
Cu	0.097	0.31	1.0	31.0
P	374.2	442.8	700	63.3
Mg	46.2	70.6	420	16.8
V	0.02	0.018	0.015	120
Fe	1.7	3.1	10-18	31-17.2
Co	0.004	0.002	0.01	20
Cr	0.14	0.15	0.04	375

The overall mineral content per 100% of the product indicates an increase in the experimental sample compared to the control sample. The experimental fish chips have a higher mineral content and meet the body's daily requirement for a number of vital macro- and microelements, including potassium (20%), zinc (18%), cobalt (20%), copper (31%), iron (31%), and phosphorus (63%). Thanks to this balanced mineral composition, the claimed product has pronounced preventative properties: it helps maintain normal cardiovascular function, improves hematopoiesis, strengthens the immune system, and participates in the regulation of enzymatic activity and energy metabolism. This combination allows fish chips to be considered not only as a food product but also as a functional component of a preventative-oriented diet.

According to the requirements of TR CU 040/2016 "On the Safety of Fish and Fish Products," established standards for residual amounts of organochlorine pesticides and heavy metals are below the permissible limits. Safety studies were conducted in an accredited laboratory of Kyrgyzstan Standard (protocols No. 921-III(1); No. 921-IY(2) (Tables 4-5).

Table 4. Content of organochlorine pesticides.

Product Name	HCH, mg/kg	DDT, mg/kg
Fish Chips No. 1 Control	0.05 (below detection limit)	0.05 (below detection limit)
Fish Chips No. 2 Experimental	0.05 (below detection limit)	0.05 (below detection limit)

Table 5. Heavy metal content.

Product Name	Content, mg/kg			
	Lead	Cadmium	Arsenic	Mercury
Fish Chips No. 1 Control	Less than 0.1	Less than 0.01	Less than 0.1	Less than 0.01
Fish Chips No. 2 Experimental	Less than 0.1	Less than 0.01	Less than 0.1	Less than 0.01

The primary requirement for the hygienic assessment of food products is the absence of pathogenic microorganisms or toxic metabolites [5]. Microbiological testing is important and relevant, as it allows for the precise and reliable confirmation or denial of the presence of infectious agents in the sample. Measuring the quantity of mesophilic aerobic and facultative anaerobic microorganisms (MAFAnM) is essential for food quality and safety control, as it is an indicator of the total bacterial count. This allows one to assess the freshness of the product, compliance with sanitary standards in production, and proper transportation and storage. An elevated count indicates the proliferation of microorganisms, including pathogenic and spoilage microorganisms.

Coliform bacteria are considered sanitary indicator microorganisms. The detection of coliform bacteria, or coliforms, in food products indicates fecal contamination. These bacteria enter food products from water, equipment, the hands of workers, and other sources. Research on microbiological indicators was carried out in an accredited laboratory of Kyrgyzstan (protocol No. 921-II(2) (Table 6).

Table 6. Microbiological indicators of fish product.

Product name	Standardized indicators and obtained results				
	QMAFANM, CFU/g	Coliforms (coliforms) in 1.0	Pathogenic, including salmonella, 25.0	Yeast, CFU/g	Molds, CFU/g
Fish Chips No. 1 Control	$1 \cdot 10^4 \pm 0.02$	Not found	Not found	$1 \cdot 10^2 \pm 0.26$ 100	$5 \cdot 10^1 \pm 0.36$
Fish Chips No. 2 Experimental	$1 \cdot 10^4 \pm 0.02$	Not found	Not found	$1 \cdot 10^2 \pm 0.26$ 100	$5 \cdot 10^1 \pm 0.36$
TR CU Standards 040/2016	$1 \cdot 10^4$	Not allowed in 1.0	Not allowed in 25.0	100	50

The study data indicate that the permissible values of microbiological safety indicators comply with the standards of TR CU 040/2016 “On the safety of fish and fish products”.

4 Discussion

The closest to the topic of the study is the method for producing chips (RU 2571791, published on 2015.12.20), in which whole anchovy is used as the fish raw material, and dry potato flakes or powder, corn starch and salt are used as recipe components, while the components are taken in the following ratio, wt. %: whole anchovy mince 29.0-37.0; potato flakes or powder 23.0-32.0; corn starch 28.0-32.0; salt 0.7-2.0. The fish raw material is ground in a grinder with a whole diameter of 2-3 mm, then the resulting minced mass is left to mature for 20-30 minutes at ambient temperature (20-25 °C); potato flakes or powder are diluted with boiling water to a puree state and cooled to the temperature of the minced

mass. The minced meat is added to mashed potatoes and mixed. Corn starch and salt are then added to the resulting mixture. The semi-finished product is formed and dried for no more than 10 minutes in an air stream at a temperature of 40-50°C. It is then fried in oil at a temperature of 180-185°C for 11-15 seconds and cooled to room temperature [6].

S. V. Kuzmin, V. G. Popov, and I. V. Mozzherina conducted research to assess the feasibility and relevance of developing fish-vegetable chips from non-traditional types of fish raw materials with the addition of a multifunctional ingredient, using rapeseed cake protein isolate as an example. This protein significantly increases the protein content of the finished product, taking into account the implementation of innovative technological processes [7].

In the studies of Utebekova G., Akhmetova N., Gurinovich G., the need for creating combined semi-finished products with an adequate replacement of plant components was substantiated, which allows for an increase in the amount of consumed dietary fiber and a decrease in the caloric content of the product, enriching minced fish with carbohydrates (polysaccharides and dietary fiber), amino acids, as well as macro- and microelements [8].

In the scientific research of Mezenova O. Ya., Barotova M. A., Bedareva O. M., Shenderyuk V. I. on the development of a technology and recipe for the production of fish-vegetable snacks "Fishnack" based on thermally modified bream tissues enriched with additives from apple cake and fish bone meal, mathematical models were obtained linking the organoleptic assessment of snacks and the main factors of the recipe for the amount of additives (%) to the total mass of dried and finely ground apple cake, as well as fish bone meal in powder form. The finished products demonstrated calcium and phosphorus saturation, demonstrated their functionality, and was recommended for athletes, schoolchildren, and the elderly as a radioprotective food [9].

A research study by Vasyukova A.T. and Krivoshonok K.V. described the use of plant-based food additives to shape the structure of semi-finished fish products with an extended shelf life. To achieve a stable gel-like structure that binds the free water in the minced fish, components such as grain and legume flour, corn flour, and chickpea flour were used. These components increased the density of the liquid fraction of the recipe, thereby structuring the minced fish, creating the integrity of the finished product and extending its shelf life [10].

Research by Fedorenko D.D., Khalturina A.A., Sutugin M.A., and Lyutova E.V. examined the range and cost of fish raw materials, fish snacks, and squid. A technology for producing fish snacks from Baltic herring (*Clupea harengus membras*) and cod (*Gadus morhua callarias*) sourced from the Kaliningrad region has been developed. Optimal parameters for the main production steps have also been established. The organoleptic and physicochemical properties of both commercial and laboratory-produced fish snack samples have been studied and determined [11].

5 Conclusions

Based on the results of the study, the following conclusions can be drawn:

- The developed recipe ensures efficient processing of low-value raw materials, reduces cutting waste, and creates a highly appealing product, enhancing its competitiveness.
- Research has confirmed the effectiveness of the proposed technology and recipe for silver carp fish chips. Silver carp is an affordable, yet under-utilized raw material due to its high bone content and the significant amount of cutting waste. At the same time, the meat of this fish contains polyunsaturated fatty acids, vitamins, and minerals, making it a valuable nutritional resource.

- The development of a fish chip recipe with the addition of auxiliary components (corn flour, pumpkin flour, starch, sodium pyrophosphate, collagen broth, lactate, and flavorings) ensured the desired texture, flavor, and technological stability of the product.
- The developed product is characterized by improved organoleptic and physicochemical properties, increased nutritional value, and can be recommended for further implementation in small-scale production and expansion of the range of functional snack products based on low-value freshwater fish.
- The developed recipe ensures efficient processing of low-value raw materials, reduces waste during cutting, and creates a product with high consumer appeal, enhancing its competitiveness.

References

1. V.P. Kulachenko, I.V. Kulachenko, A.G. Voshkin, Silver carp - a valuable object of pond aquaculture, Journal “Fisheries” 5, 70–75 (2016)
2. S.V. Garmash, Productivity in fish farming in Kyrgyzstan has almost doubled after the zero VAT rate on trout feed, Online Publication (21.11.2025). URL: https://open.kg/about-kyrgyzstan/kyrgyz-economy/industry/46614-v-kyrgyzstane-pochti-vdvoe-vyrosla-proizvoditelnost-v-rybovodstve-posle-nulevoj-stavki-nds-na-korm-dlja-foreli.html
3. *Potential for the Development of Aquaculture in Kyrgyzstan*, FAO Brochure (2024). URL: www.fao.org/faostat/en/data/FBS
4. A.Yu. Asanov, Growth rate characteristics of silver carp (*Hypophthalmichthys*) in water bodies of the Volga Upland within the Penza Region, Proc. Higher Educ. Inst. Volga Region. Nat. Sci. 1, 42–54 (2023)
5. D.R. Popkova, N.A. Frolov, O.N. Anokhina, Yu.V. Mastyugin, Study of microbiological safety indicators of meat products from game meat and livestock meat, Bull. Youth Sci. 4(6), 15 (2016)
6. R.V. Artemov, A.V. Artemov, M.V. Arnautov, *Patent*, Federal State Budgetary Scientific Institution “All-Russian Research Institute of Fisheries and Oceanography” (FSBSI “VNIRO”) (n.d.). URL: https://patents.google.com/patent/RU2571791C1/ru
7. S.V. Kuzmin, V.G. Popov, I.V. Mozzherina, Relevance of developing formulations and production technologies for fish-vegetable chips from non-traditional fish raw materials, Polzunovsky Bull. 3, 163–169 (2021)
8. G. Utebekova, N. Akhmetova, G. Gurinovich, The study of the nutritional and biological value of functional semi-finished fish products “fish balls”, Potravinarstvo Slovak J. Food Sci. 17, 43–54 (2023). ISSN: 1337-0960. DOI: 10.5219/1828
9. O.Ya. Mezenova, M.A. Barotova, O.M. Bedareva, V.I. Shenderyuk, Substantiation of formulation and technology for dried fish-vegetable snacks based on thermomodified tissues of Baltic bream, Bull. IAC 1, 52–59 (2020)
10. A.T. Vasyukova, K.V. Krivoshonok, Use of plant food additives for forming the structure of fish semi-finished products with extended shelf life, Fisheries 2 (March–April 2025), 126–131
11. D.D. Fedorenko, A.A. Khalturina, M.A. Sutugin, E.V. Lyutova, On the development of snack product technology from fish raw materials of the Kaliningrad Region, Bull. Youth Sci. 5(42), 6 (2023). DOI: 10.46845/2541-8254-2023-5(42)-8