Research Article

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Fishing as an important source of food in the Arctic and subarctic zones of Yakutia

<https://doi.org/10.1515/opag-2020-0022>
received May 19, 2019; accepted April 2, 2020

Key words: fish, Arctic cisco, Arctic, heavy metals, Yakutia

Abstract: The peculiarity of natural conditions of Yakutia plays an important role in the formation of economic activities of its population. A significant number of rivers and lakes are a favorable condition for the development and preservation of traditional fishing. Currently, more than 89% of the commercial fish catch is produced in the lower reaches of the large northern rivers and lakes in the Arctic and subarctic zones of Yakutia. The main part of this catch is whitefish species, which are valued for their fat content, protein content, culinary, and taste qualities. Fish is a valuable food product for the population of Yakutia. This article presents the results of the study on the nutritional value and the content of heavy metals in the Arctic cisco meat. The high content of fat and protein in the studied samples shows that the Arctic cisco meat belongs to high-protein and high-calorie products and has a high biological value. It was found that on average, the level of toxic metals in the Arctic cisco meat does not exceed the norms accepted in Russia for fish products. The data obtained suggest that the content of heavy metals in fish is due to the peculiarities of living conditions and environmental pollution. Over the past decades, the volume of fish production in Yakutia has been declining due to the socioeconomic and climatic factors. Due to the anthropogenic pollution of water in rivers and lakes by oil products and effluents and waste from various sectors of the economy, especially the mining industry, there is a reduction in the fish resources and there is a need to monitor the environmental condition of the fishing reservoirs and the fish food quality.

1 Introduction

The natural resources of the northern part of Russia, in particular Yakutia, are becoming increasingly important in modern conditions. The peculiarity of the natural and climatic conditions in this region plays a significant role in the formation of the traditional economy of the population. A large number of fishing rivers and lakes are a favorable condition for the development and preservation of traditional fishing.

According to the archaeological data, fishing originated in Eastern Siberia and Yakutia 6–10 thousand years ago (Everstov 1988). In the ethnographic works of the nineteenth century by Seroshevsky (1993), there is information that two-thirds of the population are engaged exclusively in fishing and hunting in the lower reaches of the great Yakutian rivers in the wet, lake-rich northern part of the region. Almost every Yakut family consumed 340 to 480 kg of carp and other lake and river fish per year. From early spring until the autumn cold, the Yakuts ate fish. Fish catch in the Yakutian waters reached the highest volume in 1942–1945 of the twentieth century and amounted to more than 10 thousand tons of fish per year. In the subsequent years, production decreased and stabilized at the level of 8000 tons. Fish catch in Yakutia per capita did not exceed 7–8 kg until 1990 and 4–5 kg during the last decade of the twentieth century (Sleptsov 2002).

Fish serves as an important source of food for the population of the north of Yakutia. The unique nutritional values of the fish contribute to survival in the harsh Arctic conditions. Fish food is a valuable source of proteins, fats, and vitamins.

Currently, fishing is one of the most important branches of agriculture in the Arctic and subarctic zones of Yakutia, where the main fishing is conducted. The Arctic zone of Yakutia covers the territories of five districts:

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Anabarsky, Bulunsky, Ust-Yansky, Allaikhovsky, and Nizhnekolymsky. The subarctic zone includes the administrative territories of the following northern districts: Oleneksky, Zhigansky, Verkhoyansky, Momsky, Abysky, Srednekolymsky, and Verkhnekolymsky. Of these, the main fishing areas are Zhigansky, Abysky, and Srednekolymsky districts (Figure 1).

In these areas of Yakutia, large fishing reservoirs are the Lena, Olenek, Anabar, Yana, Indigirka, and Kolyma rivers and lakes. Sea fishing is not conducted in Yakutia.

Over the past decades, the dynamics of gross fish catch in Yakutia is uneven, there is a decline and an increase in the volume of fish produced for certain years. So, from 1997 to 2006, the total catch of fish ranges from 3.2 to 4.6 thousand tons. In 2007, there was a sharp increase in fish catch to 7.0 thousand tons (Popova and Fedorova 2018). Since 2008, the average total catch is about 5.0 thousand tons per year (Figure 2).

Seasonal fishing, which is tied to the timing of spawning migration of fish, is conducted in almost all areas. The objects of intensive fishing are the fish of the whitefish family (*Coregonidae*): *Coregonus sardinella*, *Coregonus autumnalis*, *Coregonus muksun*, *Coregonus nasus*, *Coregonus lavaretus pidschian*, and *Coregonus peled*; the volume of production of this family of fish is more than 89% of the total fish catch.

Fish is an important component of food, and due to its taste and high nutritional and biological value, it is widely used in the daily diet and dietary nutrition of the Yakutian population. Fish and fish products contain

essential amino acids, polyunsaturated fatty acids, micro- and macronutrients, vitamins, and other nutrients. In addition, the presence of toxic metals and other pollutants in the fish products is one of the most important indicators of quality. There are data on the level of heavy metals in fish due to water pollution in the previous studies by some authors (Taylor 1983; Sorensen 1992; Eichenberger 1993; Kashulin et al. 1999; Karadede 2000; Klenkin et al. 2008; Popov 2002; Vaganov 2012; Wei et al. 2014; Zubkova et al. 2016). At the same time, although this problem has been sufficiently studied in other regions, there is little information about the levels of heavy metals in fish and the quality of fish as a food product in Yakutia.

2 Materials and methods

When writing this article, the authors used materials and observations collected during field work in the lower reaches of the Arctic rivers of Yakutia and conducted the laboratory studies to assess the quality of fish products. The Arctic cisco (*Coregonus autumnalis* Pallas), which is widely distributed in the Arctic rivers and is one of the mass objects of fishing, was selected as the material for this study.

The ichthyological material was collected during the summer–autumn of 2016–2018. Studies of some biological parameters of the Arctic cisco (Smith length, body weight of the whole fish, and age) were carried out using

Figure 1: Main fishing areas of Yakutia.

Figure 2: Dynamics of total fish catch (tons) in Yakutia over the past 10 years.

the generally accepted methods (Pravdin 1966; Mina 1976). The nutritional and biological value of the fish meat was determined by studying the biochemical composition by infrared spectroscopy (SpectraStar Analyzer model 2200; Unity Scientific, USA), calibrated based on the generally accepted standard chemical methods in the Laboratory of Biochemistry and Mass Analysis at the Federal State Budgetary Scientific Institution, Yakut Research Institute of Agriculture. The device is designed for the fast and accurate analysis of the main indicators of the quality of the agricultural and food products. The fish samples were taken from the catch sites in accordance with GOST 31339-2006.

The content of heavy metals (Fe, Cu, Zn, Pb, Hg, and Cd) in the whitefish meat was determined by atomic absorption spectrophotometry using the Spectrum-5 Analyzer at the Yakut Republican veterinary testing laboratory. The content of toxic elements (Pb, Cd, and Hg) in the fish meat was evaluated according to the SanPiN 2.3.2.1078-01. The data obtained were processed biometrically using traditional statistical analysis methods.

3 Results

The biological and ecological–geographical characteristics of the Arctic cisco are given in the previous literature (Pirozhnikov 1955; Novikov 1966; Kirillov 1972; Kirillov

2002; Ivanov 2011). Arctic cisco is a semi-passable fish that lives in the coastal areas of seas and deltas of the Arctic rivers. In Yakutia, it reaches a body length of 60 cm and a body weight of 2,100 g. The usual body length of a mature fish is 35–45 cm on average, and its mass is 500–1,500 g. It breeds in rivers and fish feeding occurs in marine brackish waters. For breeding, it rises in the areas of the middle flow of rivers around the middle of June. The mass movement of Arctic cisco is observed in the second half of July to early August. Spawning is in autumn in September–October in the areas of rivers with sandy and pebbly soils and rapid flow.

In Yakutia, the Arctic cisco are the most abundant fish in the Lena and Indigirka rivers. From the data in Figure 3, it can be seen that on average, over the past 10 years the largest volume of fish catch was observed in the lower reaches of the Lena and Yana rivers. Fish are caught with seines, stationary nets, and floating nets during annual spawning migrations upstream in summer and autumn. In winter, there is ice fishing, which is mainly done on feeding grounds and to a lesser extent during the rolling of the spawned fish.

Thus, the analysis of the Arctic cisco catch in the Lena River, which we conducted during the spawning migration, revealed that the size and age structure are relatively heterogeneous and dominating age groups are 7⁺–10⁺ years old. The spawning stock is based on fish with an average length of 47 ± 0.30 cm and a mass of $1,100 \pm 0.35$ g.

Figure 3: Catch of fish in the lower reaches of the Arctic rivers of Yakutia over the past 10 years on average (tons).

The Arctic cisco has long been widely used for food by the local population, which is stored for future use in the form of yukola. The indigenous population of Yakutia, especially in the Arctic regions, eat fresh raw fish in the form of stroganina that is provide the body with proteins of high biological value.

Fish of the Arctic rivers and lakes are rich in macro- and microelements and vitamins and are characterized by proteins of high biological value. The results of our study revealed a high content of fats and proteins in the meat of the Arctic cisco caught in the lower reaches of the Arctic rivers. The highest fat content was observed in the Arctic cisco caught in the Indigirka River. The fat content in the fish fillet was 8.45 ± 0.003 and in the fish bellies -29.32 ± 0.001 g/100 g (in the raw mass). In the fillets of the Arctic cisco from the Arctic rivers, the protein content varies between 14.90 ± 0.003 and 15.69 ± 0.001 g/100 g (in raw weight).

When assessing the quality of fish food, along with the determination of the content of nutrients, the results of indicators that allow us to determine the degree of its safety for human health are important. Toxic substances may be accumulated in the ecological chain “water – commercial fish.” Toxic elements such as lead, arsenic, cadmium, mercury, copper, and zinc are particularly dangerous for humans, as they are the consumers of the final product of the water – fish. As a result of environmental pollution, the surface waters of the basins of large rivers in Yakutia are contaminated with various toxicants, including heavy metals. The main substances that pollute water in the Lena river basin are organic substances, phenols, petroleum products, Fe, Mn, Cu, Zn, Pb, and Hg compounds, pesticides, sulfates, ammonium nitrogen, and nitrite nitrogen; in the Indigirka

river basin are organic substances, phenols, chlorides, petroleum products, Fe, Mn, Cu, Zn, Pb, and Hg compounds, and nitrite nitrogen; and in the Kolyma river basin are organic substances, phenols, chlorides, petroleum products, compounds Fe, Mn, Cu, Zn, Pb, and Hg, nitrate nitrogen, and organochlorine pesticides. At the same time, the water quality class throughout the major rivers belongs to the 4th category “A” – dirty water (Popova and Markova 2008; Abramov *et al.* 2016).

According to our study data, all the samples of the Arctic cisco examined contain largest amount of iron, copper, and zinc, but within the limits of the normative indicators. The average lead content in the meat of the commercial Arctic cisco of the lower Lena river basin is 0.35 ± 0.017 mg/kg, while that in the meat of commercial Arctic cisco of the Indigirka population is three times higher (-1.12 ± 0.068 mg/kg). A relatively high lead content, but lower than the maximum allowable concentration, was also found in the meat of the fish from the Kolyma river -0.82 ± 0.023 mg/kg and the Yana river -0.68 ± 0.040 mg/kg (Table 1).

Relatively high concentration of mercury (but not higher than the maximum permissible concentrations) was found in the fish caught in the Yana, Indigirka, and Kolyma rivers. The content of cadmium in the fish from the Yana and Kolyma rivers is relatively high but does not exceed the regulatory requirements of the SanPiN.

4 Discussion

When we studied the biological indicators of the Arctic cisco, we did not find any discrepancies with the literature data. Thus, in the study by Kirillov *et al.* (2010), conducted

Table 1: Average content of heavy metals (mg/kg) in fish

Rivers	Heavy metals					
	Fe	Cu	Zn	Pb	Hg	Cd
Lena	2.65 ± 0.101	2.52 ± 0.770	2.67 ± 0.640	0.35 ± 0.017	0.10 ± 0.001	0.005 ± 0.004
Yana	2.24 ± 0.097	2.72 ± 0.097	2.72 ± 0.080	0.68 ± 0.040	0.07 ± 0.004	0.09 ± 0.006
Indigirka	2.13 ± 0.040	2.32 ± 0.085	2.76 ± 0.430	1.12 ± 0.068	0.01 ± 0.001	0.06 ± 0.009
Kolyma	2.28 ± 0.059	2.41 ± 0.082	2.49 ± 0.065	0.82 ± 0.023	0.67 ± 0.007	0.10 ± 0.002

in the Zhigansk district, it is noted that fish of age 6⁺–12⁺ years old with a body length of 40–54 cm and a weight of 800–2000 g participate in reproduction. A positive correlation between the fertility and the length, weight, and age of the fish was found. According to Kirillov and Ivanov (2008), the average length and mass of the spawning Arctic cisco in the Indigirka river basin are relatively stable and vary between 39.76 and 40.64 cm and 898.0 and 909.5 g, respectively.

The results of our study have shown that the fish of the Arctic rivers of Yakutia are rich in proteins and fats, which is also noted in other studies (Abramov et al. 2015; Abramov et al. 2018). The meat of the commercial Arctic cisco caught in the lower reaches of the Yenisei river basin in Siberia is also characterized by a high fat content -17.9 ± 0.35 g/100 g (Gnedov 2010).

Information on the presence of heavy metals in commercial fish that live in the northern reservoirs is available in the works by other authors. Thus, the studied organs and muscle tissue of the Arctic cisco of the Lena River contain iron in the largest amount, followed by zinc and copper, and lead, cadmium, and mercury are found in the minimum amount (Popova and Markova 2013). According to Nyukkanov (2004), the largest accumulation of mercury, lead, and cadmium compounds in water, bottom sediments, and fish in the Indigirka River was found in the summer months. This is due to the more significant technogenic influence of the mining industry in the summer than in the winter, since at this time, the enterprises stop their work.

Low levels of cadmium and lead were found in the organs and tissues of the Baikal omul (Gomboeva 2003). The concentration of heavy metals in the muscle tissue of the fish from the reservoirs of the Ob river basin is low, which is lower than the permissible residual concentrations of these elements in fresh fish products in Russia.

Thus, the following conclusions can be drawn:

- based on the results of the studies of the chemical composition and nutritional value of the commercial fish, it was found that the Arctic cisco belongs to

medium-protein fish varieties, and in terms of fat content, it belongs to particularly fatty fish varieties and high-calorie foods;

- the concentration of heavy metals in the Arctic cisco meat is low and does not exceed the regulatory requirements of the SanPiN;
- intake and accumulation of toxic metals in the fish caught from different rivers vary. The highest content of them was found in the fish of the Yana, Indigirka, and Kolyma rivers, which is associated with the geochemical features of the regions and pollution of river water by the effluents from the mining industry.

5 Conclusion

Currently, the volume of fish production in the Republic is affected by climatic, socioeconomic, and environmental conditions of the fishing rivers and lakes. There are many fishing reservoirs in the Republic, which are located in remote areas with undeveloped infrastructure, where the fish resources are still inaccessible and these territories develop very slowly. An important factor is the lack of fishing enterprises that have a modern material and technical base and appropriate financial resources.

The ecological condition of the fishing reservoirs is of great importance, as the reproduction of the commercial fish populations depends on the water quality and hydrological regime of these reservoirs. Due to the pollution of rivers by objects of housing and communal services, mining, and development of oil and gas fields, the water quality of the fishing rivers and lakes in Yakutia is deteriorating every year. Waste from the diamond and gold mining industries is a major threat, and it regularly enters rivers and lakes. There is a need to constantly monitor the state of the natural environment and study the quality and environmental safety of commercial fish to provide the population of Yakutia with high-quality fish products.

Conflicts of interest: The authors declare no conflicts of interest.

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