Fakulta rybářství
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Products from aquaculture: Market, quality and new product development

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CONTENT

CHAPTER 1

GENERAL INTRODUCTION

Fish in human diet

The term "fishery products" or "seafood" includes finfishes, crustaceans, molluscs and other aquatic animals (such as sea cucumbers, sea urchins, sea squirts and edible jellyfish) produced for the intended use as food for human consumption (FAO, 2014). It excludes fish not for human consumption, such as fish oil and fishmeal and also other production from the sea such as sea mammals and plants.

A diet high in fish and shellfish appears to be beneficial to health (Lund, 2013). Fishery products are also important animal protein food resources with high biological value (Delgano et al., 2003). Seafood play an important role in human nutrition by providing amino acids, minerals, microelements, vitamins and long-chain omega-3 polyunsaturated fatty acids, which may reduce the risk of adverse cardiovascular events (Oehlenschlager, 2012; Sampels et al., 2015; Canli and Atli, 2003). According to FAO (2016), fish provides health benefits in the development of the brain and nervous system in the foetus and infants. The fundamental difference between fish and other animals is in their high levels of n-3 fatty acids such as docosahexaenoic acid (22:6, n-3, DHA), eicosapentaenoic acid (20:5, n-3, EPA) and docosapentaenoic acid (22:5, n-3, DPA) (Kris-Etherton et al., 2002; Miklavčič et al., 2010). Small fish eaten whole are very rich in zinc, calcium and other minerals compared with other animal source foods and large fish species (Larsen et al., 2000). A 150 g portion of fish can provide about 50–60 percent of an adult's daily protein requirements and the digestibility of fish is approximately 5–15% higher than plant-source foods (WHO, 1985). Some vitamins contained in seafood are sensitive to heat, sunlight and water, while other nutrients such as protein, fat, iron and calcium are stable, even after processing and cooking (Kawarazuka, 2010). In 2010, fish accounted for 16.7 percent of the global population's intake of animal protein and 6.5 percent of all protein consumed. Moreover, fish provided more than 2.9 billion people with almost 20 percent of their intake of animal protein, and 4.3 billion people with about 15 percent of such protein. Fish proteins can represent a crucial nutritional component in some densely populated countries where the total protein intake levels may be low (FAO, 2014). The world population is expected to grow from the present 6.8 billion people to about 9 billion by 2050, its reliance on farmed fish production as an important source of protein will also increase (Naylor et al., 2000; Garcia and Rosenberg, 2010). The U.S. Food and Drug Administration currently recommends that children under age 12 and pregnant or breastfeeding women should eat 2 to 3 servings of a variety of different kinds of fish and shellfish each week (Hicks, 2016).

From 1985 to 2006 the annual average increase in pork and poultry production were 2.8% and 4.9%, whereas in the same 15-year period intensive aquaculture production experienced a 10.3% annual growth rate. These trends reflect the global increase in human consumption of fish and animal proteins (Tveterås and Tveterås, 2010). Seafood is not only an important source of protein, it is also a highly traded product, which makes it a key source of income for many individuals, households, and firms across many countries (Kawarazuka, 2010; Asche et al., 2015; FAO, 2016). In 2006, fisheries and aquaculture directly employed 43.5 million people, with 520 million people indirectly deriving their livelihoods from seafood-related industries (Asche et al., 2015).

In 2014, 56.6 million people were engaged in the primary sector of capture fisheries and aquaculture. In the same year, 84 percent of the global population engaged in the fisheries and aquaculture sector was in Asia, followed by Africa, and Latin America and the Caribbean. More than 18 million (33% of all people employed in the sector) were engaged in fish farming, concentrated primarily in Asia (94 percent of all aquaculture engagement), followed by Latin

America and the Caribbean. China, where growth seems to have peaked with more than 14 million people (25 percent of the world total) engaged as fishers (9 million, or 24 percent of the world total, respectively) and fish farmers (5 million, or 27 percent of the world total, respectively). Small-scale fisheries provide work to 90 percent of the people employed in capture fisheries (FAO, 2016).

Production of seafood

The dynamics of the fishery sector reflect the complex interaction of a number of internal or external drivers, the most significant of which are demography, globalization, economic development, governance, fishing capacity, technological progress and climate change (Garcia and Rosenberg, 2010). Politicians in many countries have encouraged growth of aquaculture to increase employment opportunities in rural areas, and also out of concern for the food fish supply and the sustainability of capture fisheries (Tveterås and Tveterås, 2010). The total world´s production of seafood has increased from 65 million tonnes in 1975 to 167.2 million tonnes in 2014 (FAO, 2016).

The worldwide decline of ocean fisheries stocks has provided impetus for rapid growth in fish and shellfish farming, or aquaculture (Naylor et al., 2000). Until the 1970s, aquaculture was relatively unimportant as a source of seafood supply. Since then, however, there has been a virtual explosion in aquaculture as a seafood production technology (Asche et al., 2015). Carps (common carp, grass carp, bighead carp and silver carp) and marine molluscs fed mainly on herbivorous diets, account for more than three-quarters of the current global aquaculture output, and tilapia, milkfish and catfish contribute another 5% of the total production. Unfortunately, market forces and government policies in many countries favour the rapid expansion of high-value, carnivorous species, such as salmon and shrimp (Naylor et al., 2000).

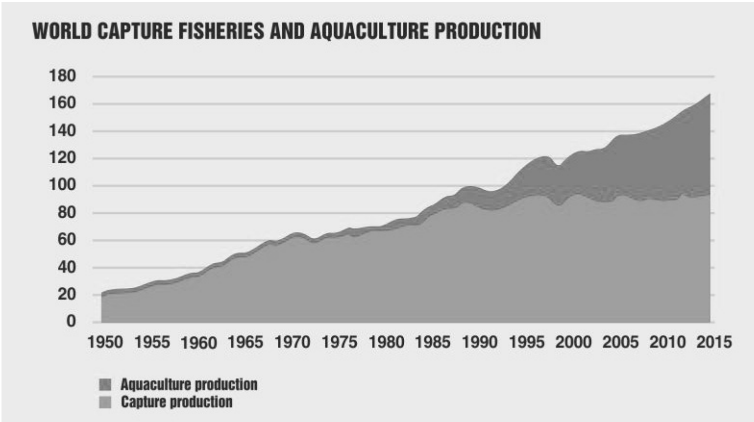
World aquaculture production can be categorized into inland aquaculture and mariculture. Inland aquaculture generally use freshwater, but some production operations use saline water in inland areas (such as in Egypt) and inland saline-alkali water (such as in China). Mariculture includes production operations in the sea and intertidal zones as well as those operated with land-based (onshore) production facilities and structures (FAO, 2014). According to Naylor et al. (2000), fish farming typically involves the enclosure of fish in a secure system under conditions in which they can thrive. Interventions in fish life cycles range from exclusion of predators and control of competitors (extensive aquaculture) to the enhancement of the food supply (semi-intensive) to the provision of all nutritional requirements (intensive). In 2012, the number of species produced in aquaculture and registered in FAO statistics was 567, including finfishes (354 species, with 5 hybrids), molluscs (102), crustaceans (59), amphibians and reptiles (6), aquatic invertebrates (9), and marine and freshwater algae (37). Aquatic species are cultured worldwide for production in a variety of farming systems and facilities of varying input intensities and technological sophistication, using freshwater, brackish water and marine water. For most farmed aquatic species, hatchery and nursery technology have been developed and established. For a few species, such as eels (*Anguilla* spp.), farming still relies entirely on wild seed (Naylor et al., 2000; FAO, 2014). In these systems, aquaculture is not a true alternative to wild harvests, but rather a means to raise wild fish to marketable size in captivity by lowering the high mortality rates characteristic of wild populations. Several systems – ponds, tanks or cages – are used in farming finfish. Most marine and diadromous finfish are reared in floating net cages nearshore, and all their nutrition is supplied by formulated feeds. Carp and other freshwater finfish are usually grown in ponds, often integrated with agricultural systems. Shrimp dominate crustacean farming and are grown in coastal ponds. Farming of both shrimp and freshwater finfish varies in its intensity and dependence on formulated feeds (Naylor et al., 2000). In 2012, global aquaculture production attained another all-time high of 66.6 million tonnes (live weight equivalent) in 2012 (US $ 144.4 billion). 92% of world aquaculture production originated from Asia, mainly China, Indonesia and India (EUMOFA, 2016). China alone produced 43.5 million tonnes of food fish that year (FAO, 2014). The most important species produced in China are freshwater fish with 27 million tonnes and molluscs with 15 million tonnes. Since 2012, China has increased its freshwater fish production by 11%. Carps, the most important species it produces, accounts for 71% of the total freshwater fish (EUMOFA, 2016). Four of the most widely cultivated fish species in polyculture systems are produced together in the same pond: silver carp (a phytoplankton filter feeder), grass carp (a herbivorous macrophyte feeder), common carp (an omnivorous detritus bottom feeder) and bighead carp (a zooplankton filter feeder). This type of system efficiently utilizes available food resources and water resources (that is, surface, pelagic and benthic) of the pond ecosystem, with the consequent effects of reducing costs and increasing productivity. As well, Czech aquaculture is well known for common carp production characterized by extensive and semi-intensive fish farming in earth ponds with annual production around 18000 tonnes. In 2014, the Czech Republic was the sixth largest producer of fish within the EU, with annual production of 20135 tonnes representing five per cent of the total European aquaculture production (FEAP, 2015; Nebeský et al., 2016).

For some types of aquaculture activity, including shrimp and salmon farming, potential damage to ocean and coastal resources through habitat destruction, waste disposal, exotic species and pathogen invasions, and large fish meal and fish oil requirements may further deplete wild fisheries stocks. For other aquaculture species, such as carp and molluscs, which are herbivorous or filter feeders, the net contribution to global fish supplies and food security is great. The diversity of aquaculture production systems leads to an underlying paradox: aquaculture is a possible solution, but also a contributing factor to the collapse of fisheries stocks worldwide (Naylor et al., 2000).

In 2012, global capture production from inland waters reached 11.6 million tonnes. According FAO (2014), global fishery production in marine waters was 82.6 million tonnes in 2011 and 79.7 million tonnes in 2012. Global inland waters capture production reached 11.6 million tonnes. The areas with the highest and still-growing catches are Northwest and Western Central Pacific. The Northern Atlantic areas and the Mediterranean and Black Sea had shrinking catches. Pelagic fish are used both for human consumption and for reduction, i.e. fishmeal and fish oil, but certain species are only fit for reduction due to their consistency, often being small, bony, and oily (Asche and Tveterås, 2004). Around one-third of global fish catches is reduced to fish oil and fishmeal for use in livestock and aquaculture feeds. The world's reduction fisheries are mainly based on fisheries of small pelagic species. Global fishmeal production is concentrated among several countries. Peru is the world's largest fishmeal producer and accounts for over 50% of global output together with Chile. Iceland, Norway and Denmark together produce around 15% of global output (Tveterås and Tveterås, 2010). Approximately 70% of the global fish catch is for direct human consumption (Kent 1997). More than a third of the total world catch goes into international trade, a figure that has risen to almost 40% in recent years (FAO, 2014). Some fisheries have declined sharply or collapsed altogether in recent years, a phenomenon that is not visible in the grand totals because other fisheries have opened or expanded. There has been widespread overfishing in coastal and shelf areas, and also on the high seas. Fisheries are endangered not only by overfishing but also by pollution and other environmental stresses in spawning and feeding areas along the coasts (Kent, 1997). The total number of fishing vessels was estimated at 4.72 million in 2012. The fleet in Asia accounted for 68 percent of the global fleet, followed by Africa (16 percent). Some 3.2 million vessels were considered to operate in marine waters

(FAO, 2014). According to Swartz et al. (2010), large numbers of industrial fishing vessels from developed countries fish in the waters of developing countries. The emergence of the United Nations Conference on Law of the Sea (UNCLOS) enabled coastal countries to claim exclusive rights to waters reaching 200 nautical miles into the open sea, including essentially all coastal shelves and their fisheries resources. Under this new regime, developed countries with established distant water fleets, could not dismantle them without significant economic and social consequences. Consequently, they began to engage in 'cash-for-access' fishing agreement. Under these arrangements, they secured fishing opportunities in the waters of developing countries in exchange for financial compensation. In some cases, fishing by foreign fleets far exceeds fishing by the host country (FAO, 2016). The ten most productive species accounted for about 24 percent of world marine capture fisheries production in 2011. Most of their stocks are fully fished and some are overfished (FAO, 2014).

Table 1. *Global production of seafood by production technology, 1950–2014 (FAO, 2016).*



Consumption

The significant growth in fisheries and aquaculture production in the past 50 years, especially in the last two decades, has enhanced the world's capacity to consume diversified and nutritious food (FAO, 2016). From the 144 million tonnes produced in 2006 by capture fisheries (53%) and aquaculture (47%), about 110 million tonnes were used for food directly and 33 million tonnes indirectly through fish meal used for aquaculture, cattle, pig and poultry farming (Garcia and Rosenberg, 2010). However, the amount of fish consumption varies with in regions. Global fish consumption has increased from an average of 10.1 kg per capita per year in 1965 to 19.2 kg in 2012 reflecting the general increase in fish consumption in most of the world's regions (Kawarazuka, 2010; FAO, 2014). In 2005, the annual per capita fish consumption of the industrialized countries stood at 29.3 kg, nearly three times that of the developing countries (10.6 kg excluding China). The difference is even greater when consumption in countries classified as 'low income and food deficient' is considered 8.3 kg (Swartz et al., 2010). In 2013, Europe and Asia increased per capita consumption by 2% and 8%, respectively, compared with 2011, while the rest of the world registered a decrease in 2013 (EUMOFA, 2016). In 2014, the world per capita fish supply reached a new record high of 20 kg (FAO, 2016). Markets of the EU, Japan and the USA which represent 12% of the world's population consume 30% of world's fish supply (Swartz et al., 2010). Sophisticated networks of trade relationships, supplied by large distant water fleets operating beyond the maritime boundaries of their home states, mean that in a large proportion of global fisheries landings are being consumed in countries outside the boundaries of the waters where the catches were taken (Swartz et al., 2010). Overall, world supply of fish for human consumption has kept ahead of population growth over the past five decades, growing at an average annual rate of 3.2 percent in the period 1961–2013, compared with 1.6 percent for world population growth. Hence, average per capita availability has risen (FAO, 2016). This impressive development has been driven by a combination of population growth, rising incomes and urbanization, and facilitated by the strong expansion of fish production and more efficient distribution channels (FAO, 2014). China has been responsible for most of the growth in fish availability, owing to the dramatic expansion in its fish production, particularly from aquaculture. Its per capita apparent fish consumption also increased an average annual rate of 6.0 percent in the period 1990–2010 to about 37.9 kg in 2013 (FAO, 2016). In 2015, 28 EU members per capita fish consumption per year was to 24.1 kg (Finfish study, 2016). Tuna was the most-consumed product in the EU, with a per capita consumption of 2.6 kg. The most consumed farmed species in EU was Atlantic salmon. It is also the species with the highest production value in the EU and its consumption surpassed 2 kg per capita in 2014 (EUMOFA, 2016). The lowest per capita consumption of fish in EU (up to 15 kg per year) can be found in the Central and Eastern EU Member States (Slovakia, Poland, Hungary). The North West EU Member States show average consumption figures between 15 and 30 kg of fish per year (Sweden) whereas people in Southern European countries eat more fish (Italy, Spain). Of all EU Member States, Portugal displayed the highest per capita consumption of fish and seafood products, 55.3 kg in 2014 (EUMOFA No. 2/2017, 2017). The Czech Republic is leading in low consumption of fish and fish products. Long-term annual fish consumption in the Czech Republic was only 4.9–5.5 kg^{-1} per capita fish consumption per year, of which only 1.3–1.4 kg was produced in the Czech Republic (Nebeský et al., 2016; Czech Fish Farmers Association, 2015). The most imported and consumed fishery product to the Czech Republic in 2010 was frozen fillets of sutchi catfish (*Pangasianodon hypophthalmus*) (from Vietnam) at a volume of 8872 tonnes and with the value of 14.9 million EUR. Since 2010, the consumption of sutchi catfish in EU and Czech Republic has declined, mainly because of health concerns and the product's perceived low quality. In 2015, the most imported and consumed fishery product was whole chilled salmon (from Norway) at a volume of 6897 tonnes valued at 35.2 million EUR (Nebeský et al., 2016). Common carp is the major produced and consumed fish from domestic aquaculture. Its annual production fluctuated from 16809 to 19 747 tonnes representing 85.8 to 88.6% of the total Czech aquaculture production during the period 2005–2014 (Czech Fish Farmers Association, 2015). Approximately 50% of marketable common carp are eaten by Czech consumers and 50% are exported to Germany and Slovakia (Nebeský et al., 2016). With approximately 250 processing plants, Poland is one of Europe's largest seafood processing countries. However, most of products are exported to the European market, including smoked salmon, canned herring, and prepared and ready-to-eat products of a variety of species. However, in 2015 the domestic market in Poland was one of the weakest in the EU, with an annual expenditure of 25 EUR per capita and a consumption of 13 kg per capita per year (Nebeský et al., 2016; EUMOFA No. 2/2017, 2017).

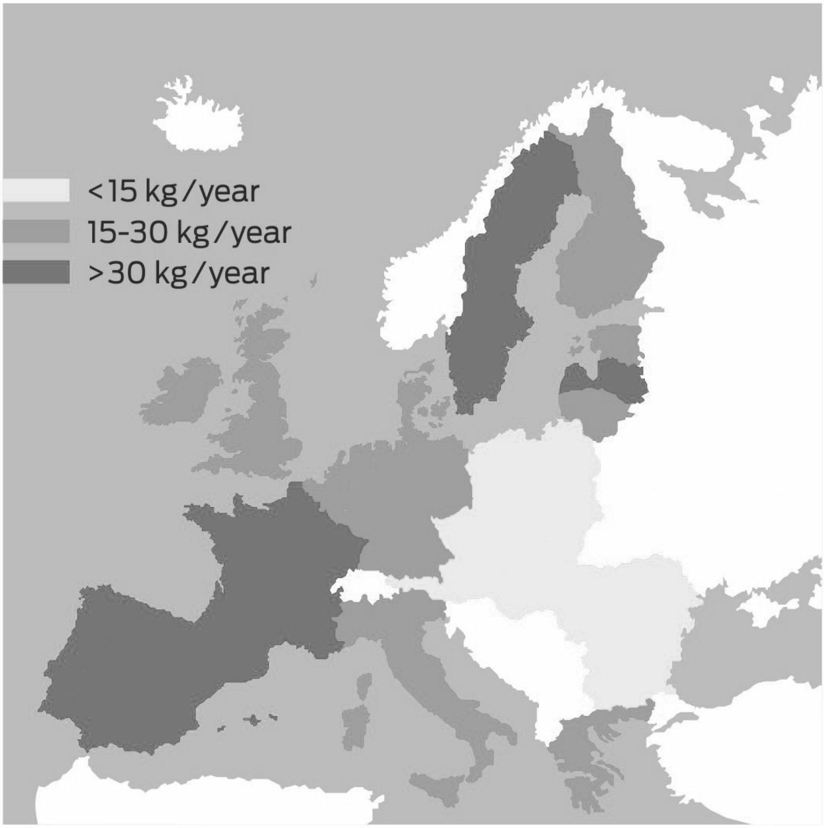


Figure 1. *Per capita consumption of fish in European Union (EUMOFA, 2016).*

Trade

Fish remain among the most traded food commodities worldwide. In general, global seafood trade can improve food security by providing access to a greater variety of foods, increasing wealth, buffering against local supply shocks, and benefit the environment by increasing overall use efficiency for some resources. However, global trade can also expose countries to external supply shocks and degrade the environment by increasing resource demand and loosening feedbacks between consumers and the impacts of food production (Gephart and Pace, 2015). Wholesalers and foodservice distributors receive both raw and processed seafood products from many different domestic and foreign sources and distribute them to retail stores and restaurants. Consumers purchase these products from retail stores for home consumption or at restaurants and other foodservice establishments (Hicks, 2016). In 2012, about 200 countries reported exports of fish and fishery products. The fishery trade is especially important for developing nations, in some cases accounting for more than half of the total value of traded commodities (FAO, 2016). In 2012, it represented about 10 percent of total agricultural exports and 1 percent of world merchandise trade in value terms (FAO, 2014). The trade of seafood is also more important than that of pork and poultry combined

(Asche et al., 2015). World statistics shows that there is a net flow of fish in the international market from developing to developed countries. Developed countries exports 85% of the value to other developed countries; meanwhile, only 15% of the value of fishery exports of developing countries was to other developing countries (Swartz et al., 2010). Developing countries export high-quality seafood in exchange for lower quality seafood (Asche et al., 2015).The increasing Asian aquaculture production is likely a primary factor for the changes in international trade flows (Gephart and Pace, 2015). China is, by far, the largest exporter of fish and fishery products. However, since 2011, it has become the world's third-largest importing country, after the United States of America and Japan. The European Union is spacious market for imported fish and fishery products, and its dependence on imports is growing (Swartz et al., 2010; FAO, 2014; EUMOFA, 2015). In terms of trade, the EU countries are increasingly dependent on imports for their fish supply. While a large bulk of their imports is of an intra-EU origin, a large amount of fish enters EU markets from developing countries. It is estimated that the EU annually imports over 9.5 million tonnes (live weight equivalent) of marine fish and invertebrates. Japan is also a major destination for marine fish export, importing approximately 5.5 million tonnes of seafood annually (Swartz et al., 2010). International fish trade is growing, and fish exports represent an important source of foreign currency for many countries. For a few countries the exports are also an essential part of the economy (Tveterås and Asche, 2008). Some developed countries, e.g. the United States of America, have reduced their aquaculture output in recent years, mainly owing to competition from countries with lower production costs (FAO, 2014). From 1994 to 2012, the total quantity of seafood traded increased by 58% and the value increased 85% in real terms. These changes signify the increasing globalization of seafood products (Gephart and Pace, 2015). International trade in fisheries products has been growing rapidly, at an annual rate of approximately 18% in the 1970s and nearly 10% in the 1980s. Much of the trade is in high-value products such as shrimp, tuna, squid, and salmon, but fishmeal is also a significant factor in international trade (Kent 1997). In 2012, of the fish marketed for edible purposes, 46 percent (63 million tonnes) was in live, fresh or chilled forms (FAO, 2014). According to (Jongwanich, 2009), the traditional (unprocessed) food exports have continuously declined and have been replaced by processed food exports. Szathmári and Molnár (2007) also indicate new trends of young consumers who purchase more processed goods or ready-to-cook seafood products. Similar trends were recorded by Nebeský et al. (2016) as increased import of fish fillets and more processed goods to the Czech Republic. Although the annual per capita fish consumption in the Czech Republic is low, import of fishery products are steadily increasing with 39098–43399 tonnes imported during the period 2010–2015 annually. The value of import increased by 81%, from 90.2 million EUR in 2010 to 169.9 million EUR in 2015. Export has grown from 18167 to 22134 tonnes, representing an increase by 21.8% in volume during 2010–2015. Trade of high value seafood products such as scallops, shrimp, lobsters and caviar have increased as a result of the growing economy of developed countries (Nebeský et al., 2016).

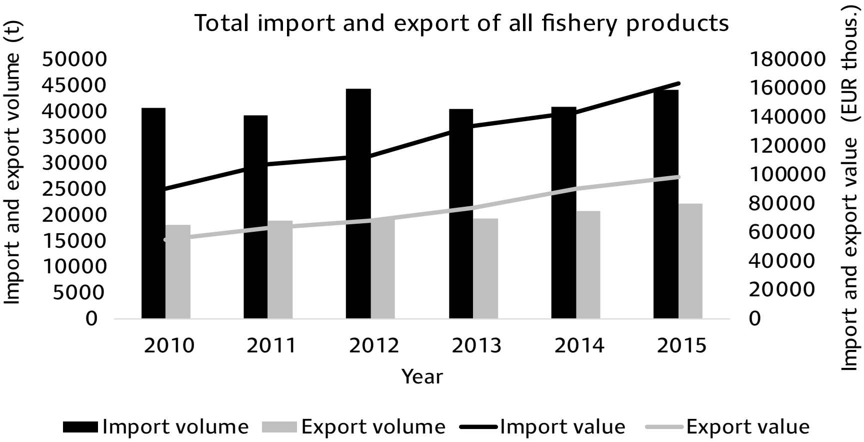


Figure 2. *Total import and export of all fishery products in the Czech Republic, 2010–2015 (Nebeský et al., 2016)*

Figure 3. *Main trade flows of fishery and aquaculture products in the world (SEUMOFA, 2016).*

Quality and New product development

Fish and other aquatic animal foods are nutritionally valuable and contain beneficial amounts of protein, lipids as well as essential minerals and vitamins. There is a clear link to health and life expectancy (Sampels, 2014). According to Domingo (2007), fishery products, quantity and frequency of their consumption, may be either beneficial or harmful. Seafood products can therefore be a potential source of contaminants and heavy metals (Sidhu, 2003) and may represent health hazard for consumers. Fishery products may contain chemical contaminants such as polychlorinated biphenyls (PCBs), organochlorine pesticides, aromatic hydrocarbons, etc. (Sidhu, 2003; Miklavčič et al., 2010; Usydus et al., 2011). According to Canli and Atli (2003), heavy metal accumulation in fish tissues is affected by ecological needs, sex and size of fish. Fish are also unique among the vertebrates, a consequence of having two routes of heavy metal acquisition, from the diet and from the water (Bury et al., 2003). The exposure of fish to heavy metals and arsenic is conditioned by the concentration of these elements in the surrounding environment, for example water and sediments (Bordajandi et al., 2003). The first methyl mercury (MeHg) derived episode, called Minamata disease, was recorded in Japan during the 1950s, and was related to the consumption of highly MeHg-polluted fish. Thereafter, more information on MeHg-related incidents were reported from Nigata in Japan and also from Iraq (Zhang et al., 2009). As mentioned above, fish consumption is the main source of MeHg exposure in humans, for example, fish consumption accounts for approximately 80–90% of the total human mercury exposure in Japan (Zhang et al., 2009).

Fish are often considered to be a problematic culinary object they spoil easily, are very prone to oxidation and often develop off-flavors due to wrong handling or incorrect storage. Seafood is potentially dangerous to health through microbial growth, chemical change and breakdown by endogenous enzymes (FAO, 2016). Those seafood products that are consumed raw or partially cooked represent the highest risk (Hicks, 2016). Therefore, post-harvest handling, processing, preservation, packaging and transportation of fish requires particular care in order to maintain the quality and nutritional attributes of fish and avoid waste and losses. The preservation of the high nutritional quality of fish is significantly influenced by several parameters such as the diet of the fish, handling and storage (Sampels, 2014; FAO, 2016; Nebeský et al., 2016). Other risks associated with environmental contaminants could be a concern for some individuals especially those who catch and eat their own fish or shellfish from lakes, rivers, streams or bays or harbors that are contaminated by environmental pollutants (Hicks, 2016).

The expansion in the consumption and commercialization of fish products in recent decades has been accompanied by food quality and safety, nutritional aspects, and wastage reduction. In the interests of food safety and consumer protection, increasingly stringent hygiene measures have been adopted at national and international trade levels (FAO, 2016). The system of Hazard Analysis Critical Control Point (HACCP) has been introduced for monitoring of critical points in the seafood journey from producer to consumer to ensure quality and safety. All parts of the seafood processing operation are examined for hazards including raw materials, ingredients, processing steps, storage, and distribution. Hazards include disease causing organisms, toxins, environmental contaminants (such as pesticides), chemicals (cleaners, sanitizers, lubricants, etc.), and physical hazards (wood, metal, and glass). For each hazard, a critical control point is identified where the potential food safety problem can be controlled. Records are kept at each critical control point so inspection agencies can be certain the HACCP system is effective in providing safe food (Hicks, 2016). According to Sampels (2014) an optimized cooling or freezing technique, in combination with antioxidant additives, irradiation, or modified atmosphere packing, can help in the preservation of both general quality, sensory and texture properties as well as the nutritional value of fish products. Progress in storage and preservation has continued, allowing a wider range of seafood products to be traded. Lastly, the improved control in the harvesting process in fisheries and throughout the production process in aquaculture has enabled producers to better meet the needs of the modern consumer and to further innovate in the supply chains (Asche et al., 2015). Fish processing is not an exact term, but may include several processes such as sorting, grading, gutting, de-skinning (peeling if shellfish), filleting, and trimming. For some fish or shellfish products, processing may include breading and filling as well as boiling, pickling, freezing and smoking and different types of packaging, e.g. canning (Thrane et al., 2009). However, additional processing methods such as thermal processing (canning, smoking etc.) should be used to make the product edible. These methods protect the product against different spoilage and pathogen microorganisms and increase the price of the product on the market. The most used methods are drying, salting and smoking, in order to extend the shelf-life of food products. These methods are based on moisture reduction and action of salt and several smoke antimicrobial elements (Arvanitoyannis and Kotsanopoulos, 2012).

Various waste and by-products are produced during the processing of seafood. At present, roe is a highly valued by-product that is always saved (Crapo and Bechtel, 2003). By-products generated during seafood processing typically range between 20 and 60% of starting raw material. This material contains valuable high-quality protein, fatty acids, vitamins, and minerals, among others (Shumilina et al., 2016). Waste and by-products produced by fisheries are currently rising, driven by both a net increase in fisheries products consumption and the changing consumer trend towards ready-to-use products (Ferraro et al., 2010). In addition, more effective utilization of by-products of fisheries, either in the production of fish feeds or directly into functional foods for human consumption are likely to play an increasingly important role (Lund, 2013). According to Crapo and Bechtel (2003) most of the fish processing by-products including heads, frames, viscera, and skin are disposed of or made into meal and oil for the animal industries. There is opportunity to produce value-added products from underutilized fish processing by-products. Development of novel products and efficient recovery of bioactive nutraceutical compounds from seafood by-products will lead to the development of more profitable processes, and will increase the economical profit and sustainability of the fishery industry (Shumilina et al., 2016; Ferraro et al., 2010).

Aims of the thesis

The main aim of this study was the evaluation of market and quality of products from aquaculture and to find the way of new product development.

The partial objectives were to:

1. Evaluate the Czech market from the perspective of import and export of fish and fish products.
2. Investigate the quality of fish sold in the Czech market from the perspective of the content of heavy metals.
3. Develop new fish products utilizing raw material from domestic fish with the aim to achieve better utilization of fish as well as to expand the products range from freshwater fish.
4. Find utilization of fish discards unfit for human consumption.

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CHAPTER 2

TRENDS IN IMPORT AND EXPORT OF FISHERY PRODUCTS IN THE CZECH REPUBLIC DURING 2010–2015

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CARP POND AQUACULTURE, PRODUCT PROCESSING AND QUALITY

Trends in import and export of fishery products in the Czech Republic during 2010–2015

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Abstract There has been a worldwide increase in consumption of fish from open waters and aquaculture during the last decades. In 2013, the Czech Republic was the sixth largest producer of fish within the EU, with annual production of 20,135 tonnes. However, during the period 2010–2015 import of fishery products to the Czech Republic increased from 39,098 to 43,399 tonnes. The monetary value of import increased by 81 % from 90.2 million EUR in 2010 to 169.9 million EUR in 2015. In 2010, the major imported fishery product was frozen fillets of sutchi catfish (*Pangasianodon hypophthalmus*) from Vietnam (8872 tonnes). In 2015, the most imported fishery product was whole chilled salmon (*Salmo salar*) from Norway (6897 tonnes). During 2010–2015, the export of fishery products increased from 18,167 to 22,134 tonnes, which is an increase by 21.8 %. The value of export has increased by 80 % from 54.5 million EUR in 2010 to 98.1 million EUR in 2015. The major exported fish was live common carp (*Cyprinus carpio*) at volume of 7545–9075 tonnes. This study looks at changes in market, volume and value of fish imported and exported during the last 6 years.

Keywords Czech · Domestic · Foreign · Market · Seafood · Trade

Introduction

Freshwater and marine fish, molluscs and crustaceans are important food resources (Usydus et al. 2011). The nutritional value and nutritional benefits are well known (Karl et al. 2014). Fish and other aquatic products represent almost 20 % of animal protein

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consumed by humans. They contain essential fatty acids and micronutrients and play an important role in global food security (FAO 2014; Sampels et al. 2015, Marine Harvest 2015). They are rich in minerals and microelements, such as calcium, phosphorus, fluorine, selenium, zinc and copper (Rebole et al. 2015), and vitamins: vitamin D, niacin, B6 and B12 (Oehlenschlager 2012; Sampels et al. 2015). The US National Institute of Health, the UK National Health Service, the Norwegian Directorate of Health and several other national health organizations recommend eating fish at least twice a week (Marine Harvest 2015). Fishery products are commodities traded on a global market through a complex series of distribution routes (Toner 2015). Consumption of fishery products depends on the level of local supplies and availability from imports. Consumption of fish and other fishery products in the Czech Republic and in other countries of Central Europe is relatively low (5.5 kg cap^{-1} $year^{-1}$) (EUMOFA 2015; FEAP 2015; Ženíšková and Gall 2015). In 2012, the world and EU fish consumption per capita was 16 and 23.9 kg cap^{-1} $year^{-1}$, respectively. The highest consumption of fish within the EU has Portugal, with 56.8 kg cap^{-1} $year^{-1}$ (EUMOFA 2015). Czech fish market is characterized by its seasonality, with common carp being major fish species produced and consumed. During the Christmas Eve, 80 % of annual common carp consumption is eaten (Adámek and Kouřil 2000). Czech retail supermarkets do not have facilities for selling fresh fish. Thus, frozen fish products are widely marketed and preferred by consumers. Retailers provide a large range of species, product forms, packaging and labels daily (Bronnmann and Asche 2016).

This study looks at the volume, the value and product structure of imported and exported fish in the Czech Republic, showing trends and fluctuations in fishery imports and exports over the 2010–2015 period.

Materials and methods

Statistics on annual import and export for the Czech Republic period 2010–2015, of seven commodity categories, have been obtained from the External Trade Database of Czech Statistical Office (Czech Statistical Office 2016) and Annual report of Ministry of Agriculture of the Czech Republic (Ženíšková and Gall 2015). These cover live fish (CN code 0301), fresh and chilled fish (CN code 0302), frozen fish (CN code 0303), fish fillets (CN code 0304), dried, smoked and salted fish (CN code 0305), crustaceans (CN code 0306) and mollusc (CN code 0307). The total volume and value of import and export of the fishery products for the above-mentioned commodity categories (CN codes 0301-0307) are compared. Volume and value of the most imported and exported fishery products in each category were assessed for their Czech market preferences. Country of origin of the major imported fishery products and the major importing countries of Czech fishery products were identified. All parameters are reported as volume (tonnes) and monetary value (million EUR). Statistical analysis was performed using the Combined Nomenclature (CN) codes 0301-0307 (Table 1). The Combined Nomenclature was established by Regulation (EEC) No. 2658/87 for goods classification. The 8-digit subheadings in the nomenclature are used in export declarations and in statistical declarations on internal trade. It is also used by Directorate General "Taxation and Customs Union" of the European Commission for customs duty purposes (EUROSTAT 2016).

This study does not include ornamental fish species within CN code 0301—live fish.

Table 1 Combined Nomenclature (CN) codes for the major commodities (FAO 2002)

CN code	Name of group	Description
0301	Live fish	Live fish
0302	Chilled fish	Fish fresh or chilled (excluding fish fillets and other fish meat of heading 0304)
0303	Frozen fish	Frozen fish (excluding fish fillets and other fish meat of heading 0304)
0304	Fish fillets	Fish fillets and other fish meat, whether or not minced, fresh, chilled or frozen
0305	Dried, salted and smoked fish	Fish fit for human consumption, dried, salted or in brine; smoked fish, fit for human consumption, whether or not cooked before or during the smoking process; flours, meals and pellets of fish, fit for human consumption
0306	Crustaceans	Crustaceans whether in shell or not, live, fresh, chilled, frozen, dried, salted or in brine, including crustaceans in shell, cooked by steaming or by boiling in water
0307	Molluscs	Molluscs fit for human consumption, whether in shell or not, live, fresh, chilled, frozen, dried, salted or in brine, including aquatic invertebrates other than crustaceans and molluscs; flours, meals and pellets of aquatic invertebrates other than crust

Results

Total import and export of fishery products (Fig. 1)

The Czech Republic is importer of fishery products, with 39,098–43,399 tonnes imported during the period 2010–2015 annually. The value of import increased by 81 %, from 90.2 million EUR in 2010 to 169.9 million EUR in 2015. Export has grown from 18,167 to 22,134 tonnes, representing an increase by 21.8 % in volume during 2010–2015 (Fig. 1). The value of export increased by 80 % from 54.5 million EUR (2010) to 98.1 million EUR (2015).

In 2010, the major imported fishery product was frozen fillets of sutchi catfish from Vietnam at volume of 8872 tonnes and with the value of 14.9 million EUR. In 2015, the

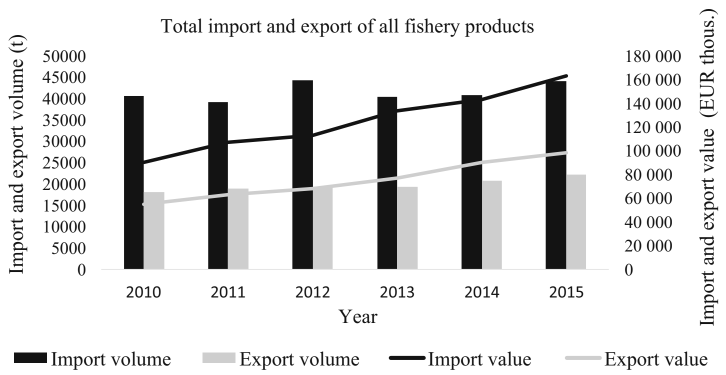

Fig. 1 Total import and export of all fishery products in the Czech Republic

major imported fishery product was whole chilled Atlantic salmon from Norway at volume of 6897 tonnes worth 35.2 million EUR. The other most imported fishery products to Czech market during the last 6 years were pelagic fish (e.g. herring (*Clupea harengus*), mackerel (*Scomber scombrus*)) and demersal fish (e.g. Alaska pollock (*Theragra chalcogramma*)). The export from the Czech Republic focused on live common carp at volumes from 7545 to 9075 tonnes, representing 36.5–42.6 % of the total export of fishery products. The monetary value of exported live common carp was 14.0 to 16.6 million EUR, representing 15.6–26.9 % of the total value of exported fishery products from the Czech Republic.

Import and export of live fish (Fig. 2)

Imported live fish represented only 0.7–4.0 % of total import of fishery products. Rainbow trout (*Oncorhynchus mykiss*) formed 37–76 % of the total import of live fish. The import of rainbow trout increased from 140 tonnes (2010) to 664.2 tonnes (2015) with a value of 0.4 million EUR and 1.86 million EUR, respectively. This represented a 474 % increase in value over the 6-year period. Average price of rainbow trout fluctuated from 2.61 to 3.00 EUR kg^{-1}. In 2010 and 2011, Slovakia imported 72 and 108 tonnes, respectively, and in 2012 Italy became the largest importer with a rise from 198 to 458 tonnes. The import to the Czech Republic of live common carp and other fish was only minor (Fig. 2). Live fish is the most important commodity produced and sold by Czech aquaculture producers. They represent 41.0–49.0 % of the total export of all fishery products, ranging from 8394 to 10,096 tonnes in volume and 16.34–19.01 million EUR in value during the period 2010–2015. Common carp represented 89–91 % of export of live fish, and Germany was the largest importer of live common carp from the Czech Republic, taking 27.6–35.6 % of the total export of this fish. This was followed by Slovakia and Poland. Other live fish for export produced mainly by the Czech pond aquaculture were tench (*Tinca tinca*) and grass carp (*Ctenopharyngodon idella*), with volumes of 682–1125 tonnes and values 1.96–2.63

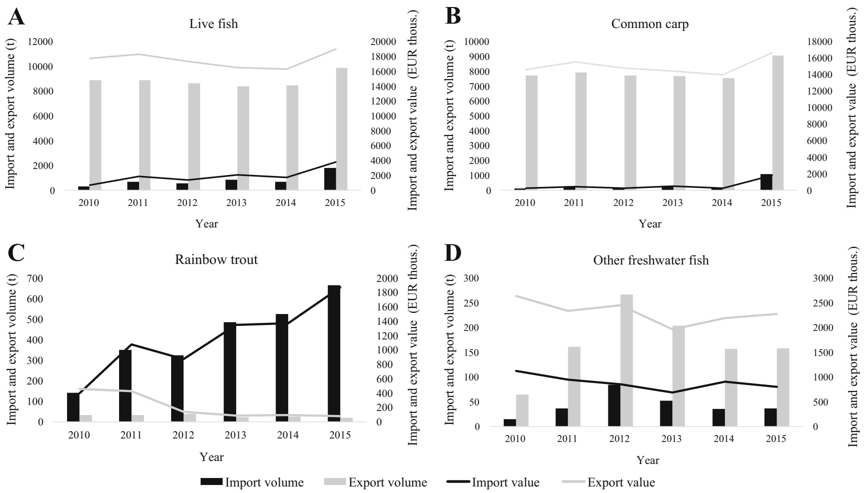

Fig. 2 Import and export of live fish with the focus on the most important species in the Czech Republic during 2010–2015

million EUR. This fish were imported mainly by Germany and Poland. Only small quantities of live rainbow trout were exported (20–31 tonnes per year).

Import and export of chilled fish (Fig. 3)

The total import of chilled fish during the period 2010–2015 increased from 2524 to 8431 tonnes and 12.9–45.9 million EUR. This represents a 300 % increase by volume peaking in 2015 (Fig. 3). Whole chilled salmon represented 76–94 % of the total import of chilled fish to the Czech Republic. In 2015, 6900 tonnes with a value of 35.2 million EUR were imported. The import price of salmon ranged from 3.96 to 5.39 EUR kg^{-1}. Norway, the largest supplier of salmon to the EU and also to the Czech Republic, provided 83.9–98.2 % of the total import. Salmon also dominates the exports from the Czech Republic. The total volume and value of export of chilled fish increased from 440.1 tonnes and 2.5 million EUR in 2010 to 4495.3 tonnes and 24.3 million EUR in 2015 (Fig. 3). Germany was a major importing country of chilled rainbow trout from the Czech Republic, with volume and value of 8–53 tonnes and 0.03–0.3 million EUR (2010–2015). However, the export of chilled rainbow trout from the Czech Republic was minor. Chilled common carp dominated among the chilled fish product export, with 134–273 tonnes and 0.33–0.75 million EUR per year.

Import and export of frozen fish (Fig. 4)

Over last 6 years, the total import of frozen fish has been steady with 6843–8080 tonnes. The value of import was 12.31–15.17 million EUR. The major frozen product was mackerel, with 48–60 % of the total import of the frozen fish to the Czech Republic. Most mackerel came from the Netherlands (45.5 % of the total import mackerel). In 2010, mackerel reached peak in volume with 4839 tonnes with a value of 5.34 million EUR at a price of 1.10 EUR kg^{-1} per kg. Other major frozen fish imported were rainbow trout

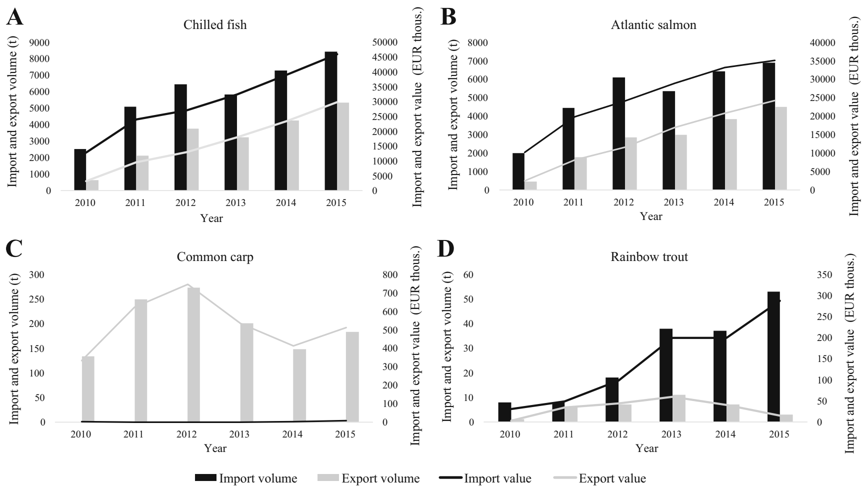

Fig. 3 Import and export of chilled fish with the focus on the most important species in the Czech Republic during 2010–2015

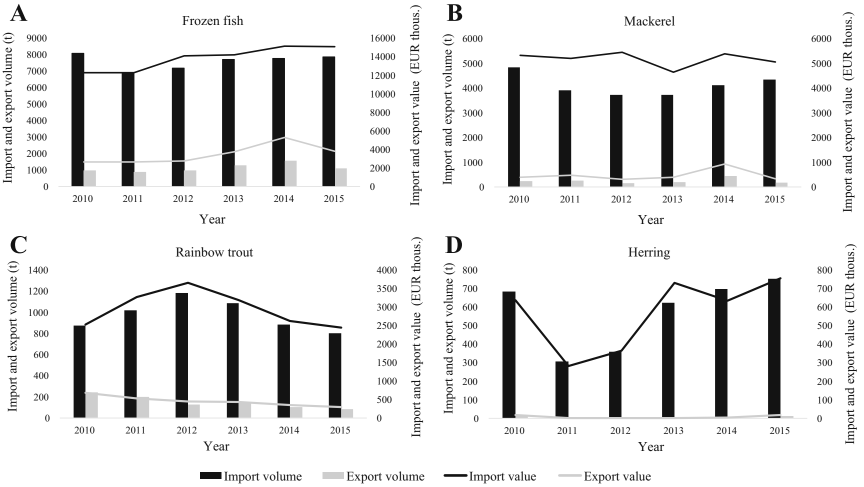

Fig. 4 Import and export of frozen fish with the focus on the most important species in the Czech Republic during 2010–2015

(801–1185 tonnes, value 2.52–3.66 million EUR) and herring (*Clupea harengus*) (307–753 tonnes, value 0.30–0.75 million EUR). These products covered 9–16 % and 4–10 % of the total import of the frozen fish to the Czech Republic. Most rainbow trout and herring came from Turkey and the Netherlands. Frozen mackerel formed 15.4–29.7 % (172–435 tonnes and 0.33–0.92 million EUR) of the total export of frozen fish from the Czech Republic. Exported frozen rainbow trout represented 82–243 tonnes and 0.29–0.68 million EUR. Export of herring was minor. Germany was the main importing country from the Czech Republic for mackerel, rainbow trout and herring. During the period 2010–2014, frozen common carp export ranged from 104 to 190 tonnes. In 2015, export of frozen common carp decreased to 34 tonnes, with exports largely to Germany and Slovakia.

Import and export of fish fillets (Fig. 5)

Fish fillets (fresh, chilled, frozen) form the largest volume of fishery products imported to the Czech Republic. Over the last 6 years, the volume of the import has been slightly decreasing, averaging 22,000 tonnes per year. The highest import of 27,007 tonnes in volume and 51.5 million EUR in value was in 2010. It represented 66.6 % of the total import of fishery products to the Czech Republic. In 2015, 22,071 tonnes fish fillets were imported worth 73.9 million EUR. This represented 50.1 % of the total import. The average price of fish fillets increased from 1.91 EUR kg^{-1} in 2010 to 3.35 EUR kg^{-1} in 2015. During 2010 and 2011, frozen fillets of sutchi catfish from Vietnam dominated the import, with 8872 and 7887 tonnes, with a value of 14.9 and 14.8 million EUR, respectively. In 2012, sutchi catfish was replaced by frozen fillets from Alaska pollock imported from China, with total weight of 3764 tonnes and value 8.7 million EUR. The import of sutchi catfish decreased to 1465 tonnes in 2015, and from 14.9 million EUR in 2010 it declined to 3.1 million EUR in 2015. Imports of Alaska pollock frozen fillets reached their peak in 2015, with 5082 tonnes worth 13.1 million EUR. The volume and the value of the import of frozen herring fillets have fluctuated from 4586 tonnes and 4.22 million EUR in

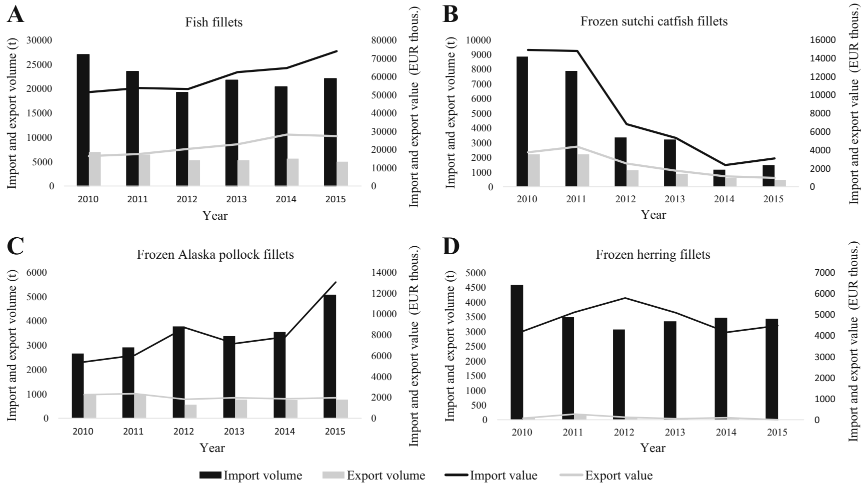

Fig. 5 Import and export of fish fillets with the focus on the most important kind of product and species in the Czech Republic during 2010–2015

2010 to 3445 tonnes and 4.48 million EUR in 2015. In 2012, the import of herring fillets was the highest, with a value of 5.79 million EUR, but the volume was at its lowest level, with 3072 tonnes. It came mostly from the Netherlands. The total volume of exported fish fillets was slightly decreasing from 6923 tonnes in 2010 to 5005 tonnes in 2015, but the value of export had risen from 16.2 to 27.2 million EUR, and the average price increased from 2.35 to 5.43 EUR kg^{-1}. Until 2011, mostly frozen sutchi catfish fillets were exported. In 2012, the export was dominated by frozen and fresh chilled salmon fillets. The export of sutchi catfish fillets continued to decline, with 2190 tonnes in 2010 to 442 tonnes in 2015. The export of Alaska pollock declined from 966 tonnes in 2010 to 753 tonnes in 2015. The value of exported Alaska pollock frozen fillets decreased from 2.25 to 1.96 million EUR. Slovakia, the main country of destination, purchased 452 to 954 tonnes of Alaska pollock fillets. The export of herring fillets was only of minor importance.

Import and export of dried, salted and smoked fish (Fig. 6)

The import of dried, salted and smoked fish was relatively low, fluctuating between 1210 and 1974 tonnes, with values of 4.38 to 9.98 million EUR. In 2012, an unusual import of an unspecified commodity (CN code 03053990) in volume of 7940 tonnes caused a sudden increase in the import in this category. The value of this import from Poland was only 0.09 million EUR, with a price of 0.01 EUR kg^{-1}. The imported product was dominated by smoked mackerel with volume ranging from 306 to 526 tonnes, and with values 0.87 to 1.45 million EUR. Most smoked mackerel came from Poland, i.e. 73.3–96.9 %. This was followed by smoked herring (volume 105–285 tonnes and value 0.19–0.49 million EUR) and smoked salmon (volume 148 to 476 tonnes and value 1.70–5.74 million EUR). The main country of origin of smoked herring and smoked salmon was Poland. The export volume and value of dried, salted and smoked fish was relatively stable and ranged from 321 to 425 tonnes and 1.39–1.89 million EUR. Smoked mackerel was the most exported fishery product, with volume ranging from 267 to 365 tonnes and 0.98–1.15 million EUR.

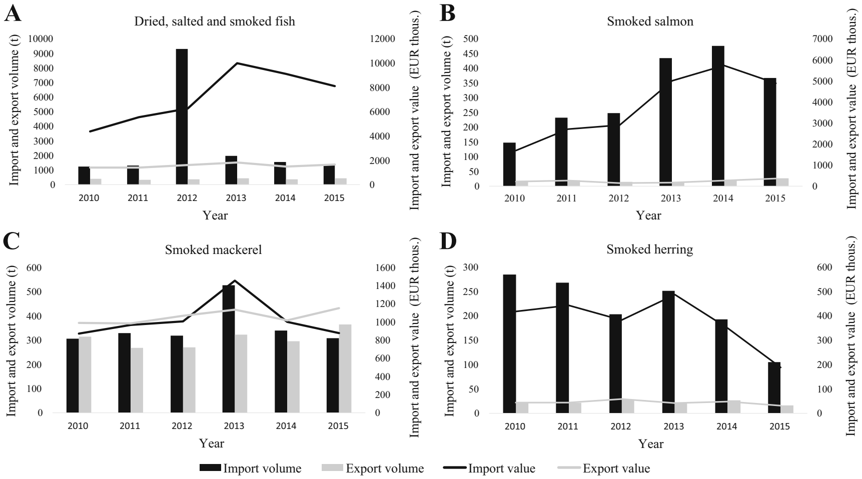

Fig. 6 Import and export of dried, salted and smoked fish with the focus on the most important kind of product and species in the Czech Republic during 2010–2015

Slovakia and Austria purchased most of the smoked mackerel, from 268 to 314 tonnes per year and with 75.5–83.7 % of the total export of dried, salted and smoked fish from the Czech Republic. The export of smoked herring and smoked salmon were of minor importance.

Import and export of crustaceans (Fig. 7)

The total import of crustaceans has shown a major increase, with the total volume and the value of the import rising from 553 to 2101 tonnes, this corresponding to an increase in its value from 3.51 to 7.66 million EUR. This represented a 214 % increase in value. Frozen prawns and shrimps from Vietnam dominated the imported crustaceans products with 44–68 % of the total crustaceans imports to the Czech Republic. Their volume and value fluctuated from 261 to 542 tonnes and 1.47–2.47 million EUR. The import of frozen prawns (*Penaeus* sp.) fluctuated from 73 to 1222 tonnes and 0.51–2.90 million EUR. Small amount of live lobster (*Homarus americanus*) was imported from Canada and UK. In 2011, it was 43 tonnes and 0.70 million EUR and in 2015 11 tonnes and 0.25 million EUR. Its unit price increased from 15.84 to 22.55 EUR kg^{-1}. The export of live lobster ranged from 1 to 7 tonnes. The total export of crustaceans fluctuated from 30 to 302 tonnes and 0.36–1.20 million EUR. Slovakia and Ukraine were the largest importers of crustaceans from the Czech Republic. Prawns of the genus *Penaeus* dominated the export with 8–30 tonnes and 0.06–0.27 million EUR. The export of miscellaneous shrimps and prawns was 16–25 tonnes.

Import and export of mollusc (Fig. 8)

The import of mollusc peaked in 2015, amounting to 1533 tonnes, worth 5.36 million EUR based on average price of 3.47 EUR kg^{-1}. The import fluctuated from 902 to 1533 tonnes and from 2.62 to 5.36 million EUR. The most imported products were snails (*Helix*

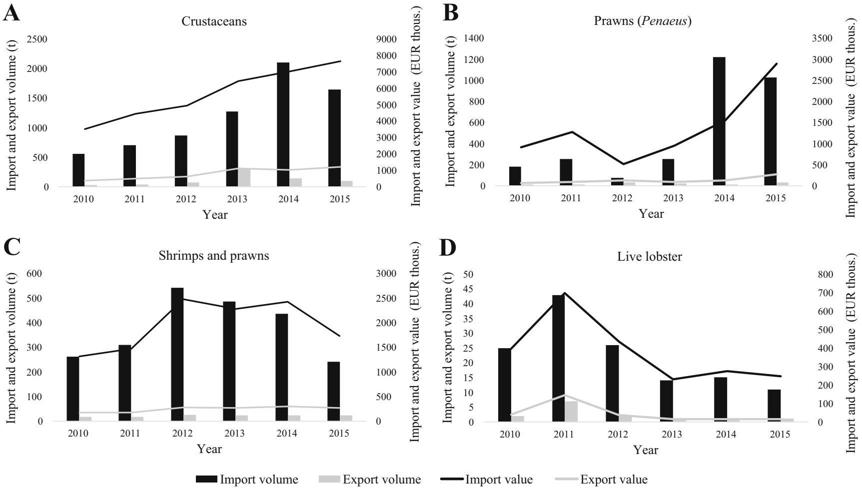

Fig. 7 Import and export of crustaceans with the focus on the most important kind of product and species in the Czech Republic during 2010–2015

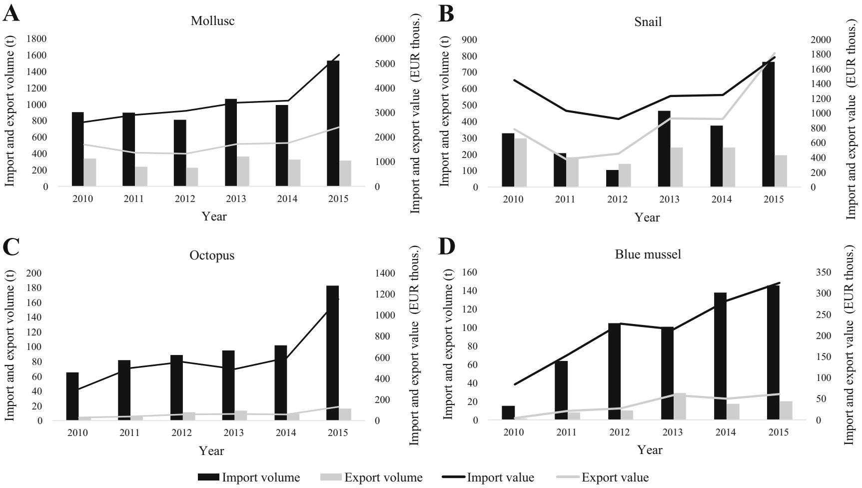

Fig. 8 Import and export of mollusc with the focus on the most important species to or from the Czech Republic during 2010–2015

pomatia), blue mussels (*Mytilus* sp.) and octopus (*Octopus* sp.). Poland, Denmark and France were the main importers to the Czech Republic. The most imported product was snails from Poland and Lithuania. Import of snails has fluctuated from 102 to 763 tonnes and 0.45–1.82 million EUR. Import of blue mussel increased from 15 tonnes in 2010 to 183 tonnes in 2015, with values of 0.08–0.33 million EUR. Denmark was the larger importer of blue mussel to the Czech Republic. The import of octopus fluctuated from 65 to 183 tonnes (value 0.30–1.15 million EUR). Main countries of origin were Morocco, Madagascar and Mexico. The export of molluscs from the Czech Republic was 226 tonnes in 2012 and 360 tonnes in 2013 (Fig. 8). The export of snails, mainly to France, fluctuated from 140 to 296 tonnes (value 0.92–1.76 million EUR). The export of blue mussel and octopus was insignificant.

Discussion

The Czech Republic is a member of the EU, which is the largest trader of fishery and aquaculture products in the world in terms of value (EUMOFA 2015). In 2013, the Czech aquaculture was the sixth important producer of freshwater fish within the EU (FEAP 2015), of which 88 % formed marketable common carp (Adámek et al. 2012; Czech Fish Farmers Association 2015). Common carp production has strong seasonal character with harvest seasons in late autumn for Christmas market and in early spring for Easter market (Adámek et al. 2012). Approximately 50 % of marketable common carp are exported to Germany (21.8–31.0 %) and Slovakia (9.9–13.2 %). An increase in consumption of domestically produced fish requires better and diversified processing of common carp and to expanding the range of fish species offered (Bondarenko et al. 2015). Some customers are also demanding organic products or carp with an increased content of unsaturated fatty acids known as Omega 3 carp. According to FEAP (2015), organic aquaculture represents around 1 % of European fish farm production. While the Czech aquaculture produces nearly 20,000 tonnes of fish per year, the Czech market is not self-sufficient and depends largely on imported fishery products. The volume of imported fishery products is twice that of coming from domestic aquaculture production (Ženíšková and Gall 2015; Czech Fish Farmers Association 2016). Current European fish market is undersupplied in most European countries, and to satisfy the demand, it depends on the import of marketable fish, mainly from the Asia–Pacific region (Policar and Adámek 2013). EU consumption is dominated by captured fish, which represents 3/4 of the total. Czech aquaculture and that of some other European countries needs further innovation, an increase in the proportion of high-value fish and other aquatic organisms, to be able to provide an all-year-around supply to consumers. Further improvements are needed in marketing (Bondarenko et al. 2015). In 2013, the total EU market for fishery products was 11.7 million tonnes, of which 8.8 million tonnes (75 %) came from import. In 2013, the Czech market imported 40,480 tonnes of fishery products, only 19,358 tonnes came from domestic aquaculture (FEAP 2015; Czech Fish Farmers Association 2016). Norway and China are the main countries from which fish products are imported to EU countries (FEAP 2015). Norway's exports to the EU have increased by 70 % since 2009. China confirmed its leading role as a processing country for cod and Alaska pollock (EUMOFA 2015). Norway is the largest exporter of chilled and frozen salmon and China the largest exporter of Alaska pollock frozen fillets to the Czech Republic. Salmon dominates the fish (by volume) consumed in the EU. It is interesting to note the increasing consumption of salmon and herring in the EU, and the stabilization of sutchi catfish imports (EUMOFA 2015). Our result confirmed these trends, excluding sutchi catfish, of which import to the Czech Republic has decreased by 85 % during last 6 years (Czech Statistical Office 2016). This decline was caused by the changes in customer preferences (Czech Fish Farmers Association 2016). Salmon is popular with retailers as it is produced under controlled environment and is stable in supply throughout the year (not subject to seasons) (Marine Harvest 2015). Smoked Atlantic salmon is the most common secondary processed product. The European market for smoked salmon was estimated at 175,000 tonnes in 2014, with Germany and France being the largest markets. The ten largest producers of smoked salmon in Europe have a market share of more than 60 %. Salmon is smoked mainly in Poland, France, UK, Baltic states and the Netherlands. The import of smoked salmon to the Czech Republic was 476 tonnes in 2014, of which Poland provided 180 tonnes (Marine Harvest 2015; Czech Statistical Office 2016). Herring has been one of the most traded species in EU since 2006 (EUMOFA 2015). Herring-made products are very popular by Czech consumers and are imported from the Netherlands and Poland (Czech Statistical Office 2016). Crustaceans have become the main EU imports in terms of value since 2012 (EUMOFA 2015). EU imports of crustaceans, especially tropical prawns from southeast Asia, were high in 2014, with 77,000 tonnes and a value of 683 million EUR. In 2014, import of crustaceans to the Czech Republic reached 2101 tonnes and a value 7 million EUR (EUMOFA 2015; FEAP 2015; Czech Statistical Office 2016). The import of mollusc to the Czech Republic is steadily increasing with peak in 2015, amounting to 1533 tonnes and a value of 5.36 million EUR (Czech Statistical Office 2016). These figures show growing demand in EU countries for higher-value fishery products. There is a growing number of customers preferring better-quality fishery products and able to afford them.

Conclusions

Import of fishery products to the Czech Republic since 2010 was relatively stable by volume but growing in value. The export of fishery products has been growing. Customers favour frozen products, which are more widely available than fresh and chilled fish, for which most Czech retail supermarkets do not have a fresh fish section. The import of higher-value commodities, such as chilled salmon and frozen crustaceans, has been increasing, and this is seen in an increasing purchasing power of customers, who are becoming more selective and choosy.

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CHAPTER 3

CONCENTRATIONS OF METALS AND MICROELEMENTS IN DOMESTICALLY PRODUCED AND IMPORTED FISHERY PRODUCTS SOLD IN THE CZECH REPUBLIC

Nebeský, V., Fedorova, G., Policar, T., Turek, J., Svačina, P., Randák, T., Kozák, P., 2017. Concentrations of metals and microelements in domestically produced and imported fishery products sold in the Czech Republic. (Manuscript)

My share on this work was about 30%.

Concentrations of metals and microelements in domestically produced and imported fishery products sold in the Czech Republic

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Key words: Mercury, lead, cadmium, arsenic, risk assessment, fishery products, Czech market

Abstract

This study compares metal and microelement concentrations in fishery products from the indigenous and foreign sources, with the objective to assess their suitability as human food. Fish production in the Czech Republic concentrates mainly at production of common carp (*Cyprinus carpio*), which formed 85.8 to 88.6 per cent of the total fish production during the period 2006 to 2014. Of this fourty to fifty per cent is exported. The Czech market depends largely on import of fishery products from other countries. The main imported products are whole marine fish or their fillets, molluscs and crustaceans represent a minor component of the import, but contain a considerable value. The following concentrations of metals and microelements have been found in the tested material. The highest and the lowest mercury concentrations were found in the muscles of blue shark (*Prionace glauca,* 0.568 mg.kg^{-1}) and tilapia (*Oreochromis niloticus*, 0.002 mg.kg^{-1}), respectively. Lead content in all seafood samples was low and close to the limit of the analytical method. The highest concentration of cadmium was found in European squid (1.015 mg.kg^{-1}). The highest and lowest arsenic concentration was in blue shark and freshwater fish (tilapia, common carp and sutchi catfish - *Pangasius hypophthalmus*). The highest nickel, copper and zinc contents were registred in molluscs, low concentrations were present in other fishery products. The results confirm that the levels of metals and microelements in the domestically produced and imported fishery products marketed in the Czech Republic are within the allowable limits.

Introduction

Freshwater fish and marine fish, moluscs and crustaceans are important food resources (Kris-Etherton et al., 2002; Fernandes et al., 2015). They play an important role in human nutrition by providing essencial fatty acids (Sampels et al., 2015) amino acids (Schwarz et al., 1988; Buchtová et al., 2007) and minerals, such as calcium, phosphorus, fluorine, selenium, zinc and copper (Rebole et al., 2015), and vitamins: vitamin D, niacin, B6 and B12 (Oehlenschlager, 2012).

Fish also may contain chemical contaminants such as metals (cadmium, lead, mercury, nickle and arsenic), microelements (copper and zinc), polychlorinated biphenyls (PCBs), organochlorine pesticides, aromatic hydrocarbons, etc. (Miklavčič et al., 2010; Mahaffey et al., 2007, Usydus et al., 2011). Fishery products, quantity a frequency of their consumption may be either beneficial or harmful (Domingo, 2007). Fish and other fishery products can therefore be potential source of contaminants (Sidhu, 2003) and may represent health hazard for consumers. In the Czech Republic consumption of fish and other fishery products is low, below the level recommended by nutritionists (MZe ČR, 2013; Sampels et al., 2015).

Consumption of fishery products depends on the level of local supplies and availability from imports. Knowledge of the origin of fishery products is important for consumer´s (Pieniak et al., 2013). In the Czech Republic fish products come from extensive or semi-intensive fish farming ponds, with common carp (*Cyprinus carpio*) being the most dominant species (around 88%). It is produced in polyculture stocks (Adámek et al., 2012a). The other species produced in polyculture are Chinese carps (grass carp – *Ctenopharyngodon idella*, bighead – *Hypophthalmichthys nobilis* and silver carp – *Hypophthalmichthys molitrix*). Sometimes they are also produced together with other species, such as tench – *Tinca tinca*, pike – *Esox lucius*, pikeperch – *Sander lucioperca*, European catfish – *Silurus glanis* and perch – *Perca fluviatilis*. Intensive salmonids production is carried out in raceways, channels or earthen ponds. Annual production is close to seven hundred tonnes of marketable rainbow trout – *Oncorhynchus mykiss*, which is insufficient for the Czech market (Adámek and Kouřil, 2000; Adámek et al., 2012b). Therefore the Czech market, like other European markets, has to be supplemented by import of of several freshwater or marine fish species, crustaceans and molluscs (MZe ČR, 2013; Policar and Adámek, 2013).

The objective of this study was to analyse the concentrations of metals and microelements in the most important representative of the current Czech fish production, as well as of the imported marine fishery products sold in the Czech market, to assess their safety and hazard for consumers.

Materials and methods

Fish production and import of fishery products to the Czech Republic

Statistics on fish production in the Czech Republic for the period 2005 to 2014 have been obtained from the following sources: FAO - Fisheries and Aquaculture Information and Statistics (FAO, 2015), The information brochure of Czech aquaculture (Czech Fish Farmers Association, 2015a), Annual report of Ministry of Agriculture of the Czech Republic related to fish production (Ženíšková and Gall, 2014) and Annual report of Federation of European Aquaculture Producers (FEAP, 2015).

Information on annual import of fishery products to the Czech market for the period 2005-2014 was obtained a processed from the External Trade Database of Czech Statistical

Office (Czech Statistical Office, 2015). The same data source was used for annual import statistics of the most important fish species imported to the Czech market in 2014.

All mentioned statistics provided basic information about the most important fishery products marketed over the last ten years in the Czech Republic. On basis of that, samples were collected from the Czech markets for an asessment of major metal and microelements concentrations in the major marketed products. The results should provide information on whether the products satisfy health and safety standards.

Collection of samples for analysis

Samples from more frequently retailing fishery products were collected during July 2014. From the most common products more samples were tested (Table 1). The samples were taken either from fresh or frozen material as offered in shops Purchase were either whole fish, molluscs or crustaceans, or fillets.

The whole fresh fish were skinned and filleted. Samples of muscle tissues from fish filets were taken from below the dorsal fin. Whole mussels, schrimps and squids or their edible parts have been used. Edible parts of five fresh mussels and shrimps were homogenized as one sample. Each squid was homogenized individually. Homogenized samples were stored in polythene bags in freezer at -18 °C. Frozen seafood were gradually thawed at 4 °C and samples were collected in the same way as in fresh sefood. Subsequently, the samples were frozen at - 18 ° C. Most chemical analyses were done on samples from individual specimens, only for shrimps and mussels five individuals were pooled into one sample to obtain at least a 20 g sample for further analysis.

Collected samples were transported in a cooler to the Laboratory of Environmental Chemistry and Biochemistry of Faculty of Fishery and Protection of Waters, University of South Bohemia (Czech Republic) for further analyses. In total, 93 samples, obtained from Czech markets, were analysed for metal and microelement content to assess their safety level for consumers.

Analytical methods

Analyses for toxic metal (mercury – THg, lead – Pb, cadmium – Cd, nickel – Ni, arsenic – As) and for potentially toxic microelements (copper – Cu, zinc – Zn) were carried out in the laboratory of the State Veterinary Institute in Prague. This Institute is fully accredited for analyses in accordance with with EN ISO/IEC 17025: 2005. Mercury content in muscle samples was measured by cold vapor atomic absorption spectrometry on an AMA-254 (Altec Ltd, Czech Republic) single-purpose mercury analyzer (detection limit 0.001 $mg.kg^{-1}$; recovery 82±6%).

Nickel, lead, cadmium, copper, zinc and arsenic concentrations were determined by ICP-MS (detection limits: Ni 0.05 $mg.kg^{-1}$, Pb and As 0.02 $mg.kg^{-1}$, Cd 0.002 $mg.kg^{-1}$ recoveries). All samples were analysed directly after their homogenization.

Statistical evaluation

The results were statistically evaluated using Statistica 8.1. for Windows software (StatSoft Inc., USA). A two-ways analysis of variance (ANOVA) was used to test metal and microelement concentrations and differences among the analysed fish, crustaceans and moluscs. Post hoc comparisons were done using Tukey's Honestly significant difference (HSD) test for comparison of metal and microelement contamination in all seafood. Significance was accepted for values of $P < 0.05$. Statistical evaluation was not applied where less than two samples were available (all species of shrimp and blue mussels). These seafood are included in results for not statistically comparision of metal and microelemet contamination.

Results and discussion

Fish production in the Czech Republic

The statistics show steady primary during the period 2005 to 2014 fish production in the Czech Republic fluctuated from 19 358 – 21 010 tonnes of live marketable fish. There are no statistics available for aquatic invertebrates (Table 2). In 2014, the fish production from aquaculture was 20 135 tonnes, representing five per cent of the total European aquaculture production (FEAP, 2015). Of the production for the period from 2006 to 2014 41.1 - 50.5% was exported, mainly to Germany, Austria, Poland and France (Czech Statistical Office, 2015). The rest of marketable fish (10 121 – 12 195 tonnes) was sold in the Czech Republic as live fish (74.5 - 82.4%) or fillets (fresh, frozen or smoked) and other products (17.6 - 25.5%) (Czech Fish Farmers Association, 2015a; Czech Statistical Office, 2015). Common carp is the major produced and commonly. Its annual production fluctuated from 16 809 to 19 747 tonnes representing 85.8 to 88.6% of the total Czech aquaculture production.

During this period annual fish consumption in the Czech Republic was only 4.9 – 5.5 kg/cap/year (Mráz et al., 2012b; Ženíšková and Gall, 2014; Czech Fish Farmers Association, 2015a) of which 1.3 – 1.4 kg was produced in the Czech Republic. There are several reasons for the low fish consumption. One is that common carp is harvested only seasonally, i.e. in autumn or in spring. The other is that only small part of the harvested fish is further processed (MZe ČR, 2013). Czech aquaculture as well as that of some other European countries need further innovation, an increase in the proportion of higher-value fish and other aquatic organisms, to provide an all-year-around supply to consumers. Further improvements are needed in marketing (Policar and Adámek, 2013; Policar et al., 2013; Sampels et al., 2015).

Fishery product import to Czech market

Seasonality of the Czech fish harvest, and that fish production concentrates mainly at one species, of which a high proportion is being exported, requires that Czech markets are strongly supplemented by imported marine and freshwater fishery products (Czech Statistical Office, 2015). Total Import of fishery products by volume is twice as high as domestic fishery production (Table 3) and four times that of the Czech production found on shelves in markets (Czech Fish Farmers Association, 2015b). It means that the ratio of fishery product consumption in food of a Czech is 4:1, that is four times more of imported fish, molluscs, prawns is consumed than originating from domestic production. This equals to the range of annual imports (period 2006 to 2014) of 3.6 – 4.1 kg of fish, both marine and freshwater, 0.02 – 0.20 kg of custaceans, and 0.04 – 0.14 kg of molluscs per capita, as compared to 1.3 – 1.4 kg of the locally produced fish (Czech Statistical Office, 2015).

During the period 2006 to 2014 the import of live, fresh, chilled, frozen and smoked whole fish and fish fillets annualy fluctuated from 37 127 to 42 645 tonnes what accounts to 92.4 – 98.1% of the total seafood import to the Czech Republic. Import of molluscs is minor compared to fish and fluctuated from 467 to 1470 tonnes or 1.2 – 3.4% of total seafood import to the Czech Republic. Import of molluscs was the highest in 2008 and 2009 (1476 and 1470 tonnes, respectively), during 2013 a 2014 declining to 1064 and 989 tonnes. Current mollusc import is nearly double of those in 2005 and 2006. Import volume of crustaceans has been rising from 237 tonnes in 2005 to 2098 tonnes in 2014 (Table 3.) Import of crustaceans (mainly shrimps) over the last decade increased almost nine times, from 0.6 to 5.2 per cent of the total fishery product import (Czech Fish Farmers Association, 2015a; Czech Statistical Office, 2015). This has resulted in an increase in their consumption from 0.02 to 0.20 kg/cap/year. There is no domestic commercial production of crustaceans in the Czech Republic (Policar and Kozák, 2015).

Most imported fishery products (45.2 - 67.5% of the total) come as processed fish fillet s in fresh, chilled and frozen conditions. The second most important fish import are frozen whole fish, which represent 16.8 – 25.7% of the total. Smoked and dried fish form, with a maximum of 21.7% reached in 2012. The usual range has been 2.9 – 5.2% of the total. Imported fresh and chilled whole fish formed 3.4 – 19.1 per cent of the total. Live fish represent only 0.5 – 2.2% of the total import (Table 3) (Czech Czech Fish Farmers Association, 2015b; Czech Statistical Office, 2015).

Atlantic salmon dominates the fish import. On the market it appears as fresh or chilled whole fish or frozen fillets. In 2014 it represented 19.7 per cent, ie 8 068 tonnes of all imports (Table 4). Atlantic salmon has very good reputation in Czech hotels, restaurants or supermarkets where maily fresh or chilled salmon is offered and consumed. It is preferred by consumers for its low bone content and low fish odor. Frozen fillets are also used, as well as fresh or chilled, but they sell for a lower price (Czech Statistical Office, 2015).

The other most the most important fish species imported to Czech market in 2014 were herring, mackerel, walleye pollock and European hake. Herring has been used as a basic raw material for manufacturing most of the marinated fish products. Hot smoked seafood has been prepared from frozen whole mackerels. Walleye pollock and European hake are very popular as fillets for preaparation of home made and public catering dishes. Imported prawns of genus *Panaeus* are mainly used as special dish in restaurants and households. Import of sutchi catfish to the Czech Republic has been decreasing from from 2010 level (9000 tonnes) to the current 1139 tonnes. Sutchi catfish has been imported primarily as frozen fillets for preparation of home made and public catering dishes and its sales are declining (Table 4) (Czech Statistical Office, 2015). The mentioned 7 species represented 61% of the total import of fishery products and it shows their importance in the Czech fishery market (Czech Fish Farmers Association, 2015a; Czech Statistical Office, 2015).

Metal content in fishery products sold in the Czech market

Concentrations of mercury, lead, cadmium and microelements in domestic and imported fishery products are given in Tables 5a, 5b and 5c. Health limits for the Czech Republic and European Union are given in Table 6.

Mercury

The highest total mercury content was detected in the muscle tissue of shark (0.568 ± 0.038 $mg.kg^{-1}$). High mercury content was detected in wild sea bream B (0.131 ± 0.018 $mg.kg^{-1}$) caught in Northeast Atlantic (FAO 27). Similar results were obtained by Miklavčič et al. (2010). Even concentration in wild sea bream B is much lower (3.8 times) than the maximum permissible limit 0.5 $mg.kg^{-1}$. The results obtained for mercury content in analysed seafood were confirmed with literature data regarding the presence of the highest mercury levels in predadory fish (Dabeka et al., 2011). According to the European Commission Regulation (EC) No. 1881/2006 the maximum allowed level of mercury (1 $mg.kg^{-1}$) can be tolerated in the following predatory fish such as shark, swordfish and tuna, because being at the top of the food chain these aquatic organisms concentrate mercury. In this respect one could consider the value of 0.568 $mg.kg^{-1}$ measured in shark as being acceptable.

The other investigated freshwater and saltwater fish, crustaceans and molluscs have very low concentrations of mercury (0.13 – 0.51 $mg.kg^{-1}$) which corresponds to findings in other studies (Storelli et al., 2012; Pastorelli et al., 2012; Orban et. al, 2012; Čelechovská et al. 2007; Sedláčková et al. 2014). Mercury concentrations found in common carp muscle tissue were low (0.023 ± 0.024 $mg.kg^{-1}$) because this fish is produced in freshwater fish ponds with low mercury concentrations, if any. This was alsso found in studies by Maršálek et al. (2007), Žlábek et al. (2005) and Svobodová et al. (2002).

The lowest total mercury content was recorded in walley pollock (0.006 ± 0.018 $mg.kg^{-1}$) caught in Northwest and Southwest Pacific (FAO 61/81), sutchi catfish (0.004 ± 0.004 $mg.kg^{-1}$) cultured in Vietnam, and in tilapia (0.002 ± 0.001 $mg.kg^{-1}$) cultured in China. Our results are at variance with the results published by Ferrantelli et al. (2012), who found mercury content of 0.41 ± 0.08 $mg.kg^{-1}$ in sutchi catfish fillets. However, other studies confirmed our results of low metal content in sutchi catfish fillets (Orban et. al, 2012; Littlea et al. 2012; Szlinder-Richert et al., 2011). Rearing tilapia or sutchi catfish in warm climates of South-East Asia takes only several months. According to Amin et al. (2012), sutchi catfish may grow from 25 mm fingerlings to over 200 g heavy fish in ninety days. It may be the reason for its low mercury content. In the tested material the mercury content was below the maximum permissible level of 0.5 $mg.kg^{-1}$ and in the Czech Republic this does not represent risk for consumers.

Lead

Most analysed seafood had lead levels below the LOQ – limit of quantification (0.02 $mg.kg^{-1}$). The highest lead content was found in imported blue mussels cultured in Italy (0.170 $mg.kg^{-1}$). The similar Pb content in blue mussels (0.166 ± 0.058 $mg.kg^{-1}$) was detected by Pastorelli et al. (2012). Lead content ranging 0.02 – 0.03 $mg.kg^{-1}$ was recorded from shrimp A cultured in China (0.03 $mg.kg^{-1}$), shrimp B captured in Western Central Pacific FAO 71 (0.02 $mg.kg^{-1}$) and in squid caught in Northeast Atlantic FAO 27 (0.03 ± 0.008 $mg.kg^{-1}$). Olmedo et al. (2013) found very similar Pb levels in frozen shrimp (0.03 $mg.kg^{-1}$) and higher Pb levels in canned cockles and mussels (0.548 and 0.202 $mg.kg^{-1}$ respectively). In the present study, the highest lead concentrations in fish were found in Atlantic salmon cultured in Norway (0.02 $mg.kg^{-1}$) and sea bream A cultured in Greece (0.02 $mg.kg^{-1}$). Similar values were found by Olmedo et al. (2013) and Guérin et al. (2011). Any analysed seafood in the present study did not exceed the maximum permissible level of lead stated by the European Commission Regulation (EC) No. 1881/2006 (0.30 $mg.kg^{-1}$ for muscle of fish and invertrebrates). Lead contamination of sefood consumed in the Czech Republic does not represent risk for consumers.

Cadmium

The higest values of cadmium were found in tissues of shrimp and molluscs (Table 5). These organisms cumulate cadmium in their tissues (Quetglas et al., 1999). European commission Regulation No. 1881/2006 for cadmium in crustaceans is 0.5 $mg.kg^{-1}$ and for bivalve molluscs and cephalopods is 1.0 $mg.kg^{-1}$ (Table 6). Our samples of squid tissue had cadmium content (1.015±0.671 $mg.kg^{-1}$), which value exceeded mentioned limit for customer safety and health (1.0 $mg.kg^{-1}$) valid for cephalopods. Increased cadmium content in marketed cephalopods also found (Manso, 2007; Storelli et al., 2012, Pastorelli et al., 2012; Olmedo et al., 2013). All cephalopods are carnivorous, feeding mainly on crustaceans, small fish, and other cephalopods (Quetglas et al., 1999). This may be the reason of higher storage of cadmium in their tissues. Higher content of cadmium was detected in blue mussels (0.073 $mg.kg^{-1}$) cultured in Italy, shrimp C (0.017 $mg.kg^{-1}$) caught in Northwest Atlantic (FAO 21) and shrimp D (0.012 $mg.kg^{-1}$) cultured in Bangladesh. Olmedo et al. (2013) found very similar higher Cd levels in blue mussels (0.110 $mg.kg^{-1}$) and shrimps from Atlantic (0.029 $mg.kg^{-1}$). According to the European Commission Regulation (EC) No. 1881/2006 gives the maximum allowed level of cadmium in fish as 0.05 $mg.kg^{-1}$. The highest cadmium content was found in blue shark (0.024 $mg.kg^{-1}$) caught in Central Eastern Atlantic (FAO 34) and herring (0.012 ± 0.010 $mg.kg^{-1}$) caught in Northeast Atlantic FAO 27. Our value (Table 5b) is in contrast with Olmedo et al. (2013) who reported very low cadmium level in fresh blue shark (0.003 $mg.kg^{-1}$). Other samples of fishery products in the present study showed very low levels of cadmium content close to or below the detection limit of analytical method (0.002 $mg.kg^{-1}$).

Nickel

Nickel may have a negative impact on human health if its levels exceed allowable limits in fishery products.The WHO limits maximal daily intake of nickel at a concentration of level 0.1 – 0.3 $mg.kg^{-1}$ Ni per capita (Lavilla et al., 2008). In this study 44 per cent of samples had concentrations below detection level (0.05 $mg.kg^{-1}$). The highest content of nickel was found in European squid (1.133 ± 1.242 $mg.kg^{-1}$) caught in Northeast Atlantic FAO 27. The high content of nickel was found in Atlantic salmon (0.265 ± 0.075 $mg.kg^{-1}$) cultured in Norway, walley pollock (0.200 ± 0.030 $mg.kg^{-1}$) caught in Northwest and Southwest Pacific (FAO 61/81), blue mussel (0.160 $mg.kg^{-1}$) cultured in Italy and Patagonian grenadier (0.145 ± 0.095 $mg.kg^{-1}$) caught in Southwest Atlantic FAO 41. Copat et al. (2008) observed similar concentrations of nickel in marine fish with a range of 0.011 – 0.327 $mg.kg^{-1}$. Our results are in contrast with Lavilla et al. (2008) who found significantly higher level of nickel concentrations in squid (7.65 ± 0.47 $mg.kg^{-1}$), shrimp (4.9 ± 0.3 $mg.kg^{-1}$) and blue mussel (2.94 ± 0.09 $mg.kg^{-1}$). Freshwater fish and shrimp analysed in this study showed very low nickel content ranging from 0.05 to 0.09 $mg.kg^{-1}$.

Arsenic

None of the tested organisms had levels of arsenic reaching the maximum permissible limit. The highest arsenic value was found in shrimp C (7.19 $mg.kg^{-1}$) as is shrimp C. Other seafood with higher As levels were marine fish such as blue shark (4.06 $mg.kg^{-1}$), sea bream B (2.96 $mg.kg^{-1}$), blue mussel (2.31 $mg.kg^{-1}$), mackerel (2.107 $mg.kg^{-1}$) and freshwater brook trout (1.21 $mg.kg^{-1}$). Lavilla et al. (2008) found higher arsenic concentration in blue mussel (12.6 ± 0.4 $mg.kg^{-1}$). However, Olmedo et al. (2013) recorded only 0.222 $mg.kg^{-1}$ in blue mussel. Very low arsenic content (0.072 ± 0.074 $mg.kg^{-1}$) in this study was found in sutchi catfish cultured in Vietnam and tilapia (0.04 ± 0.022 $mg.kg^{-1}$) from China. These levels are very similar to those recently found by Olmedo et al. (2013) and Schenone et al. (2013) for the same species: sutchi catfish had 0.021 $mg.kg^{-1}$ and in tilapia the concentration was below the limit of detection (0.02 $mg.kg^{-1}$). The arsenic content in tissue of common carp from Czech pond aquaculture was very low (0.061 ± 0.023 $mg.kg^{-1}$) which corresponds with the results published by Čelechovská et al. (2007).

Microelements in fishery products

Copper

Copper is an essential constituent of many enzymes, carefully regulated by physiological mechanisms in most organisms. It is an essential element in daily human nutrition. However, it can also be toxic at high concentrations (Celik and Oehlenschlager, 2005; Zubcov et al., 2012; Storelli, 2009; Storelli et al., 2010). The highest content of copper in our study had found in European squid (26.8 $mg.kg^{-1}$). This corresponds with the results of Storelli et al. (2010), who found a concentration of 37.37 $mg.kg^{-1}$. The highest content of Cu in fish samples was detected in herring (2.68 ± 4.532 $mg.kg^{-1}$) and mackerel (0.747 ± 0.175 $mg.\ kg^{-1}$). High levels of copper were measured in shrimp C and shrimp D (7.27 $mg.kg^{-1}$ and 4.620 $mg.kg^{-1}$, respectively). Olmedo et al. (2013) also observed high copper levels in crustaceans and cephalopods: frozen prawn (6.865 $mg.kg^{-1}$) and shrimp (3.766 $mg.kg^{-1}$), canned octopus (3.407 $mg.kg^{-1}$) and frozen squid (2.959 $mg.kg^{-1}$). All other concentrations of Cu measured in tissues of our samples fluctuated between 0.133 - 0.450 $mg.kg^{-1}$ and are comparable with values obtained by other authors (Zubcov et al. 2012; Celik and Oehlenschlager 2005; Čelechovská et al. 2007; Usydus et al., 2009). The lowest copper concentration was obtained in sutchi catfish (0.100 ± 0.029 $mg.kg^{-1}$). The intake of cooper in food fish and shellfish would not pose any risk for the average consumer (Storelli et al., 2010).

Zinc

The highest concentrations of zinc in our study were found in samples of blue mussel (17 $mg.kg^{-1}$) and European squid (10.907 ± 1.462 $mg.kg^{-1}$). Generally, mollusc tissue contain the highest concentration of zinc (Celik and Oehlenschlager, 2005; Storelli, 2009), which accumulates mainly in hepatopancreas, gonads and gills (Adami et al., 2002). These concentrations suggest that mussels could represent key source of Zn in human diet. All samples of shrimp in this study contained high levels of zinc ranging form 7.72 to 10.3 $mg.kg^{-1}$. High Zn concentrations were found in herring (6.07 ± 5.21 $mg.kg^{-1}$) caught in Northeast

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Atlantic FAO 27, sea bream A (5.10 ± 0.59 mg.kg^{-1}) cultured in Greece and mackerel (3.77 ± 0.697 mg.kg^{-1}) caught in Northeast Atlantic FAO 27 (Table 5). Similar results were reported by Copat et al. (2013) and Olmedo et al. (2013) for mackerel, 4.875 mg.kg^{-1} and 8.090 mg.kg^{-1}, respectively. Olmedo et al. (2013) also found very similar Zn levels to ours in blue mussel (14.173 mg.kg^{-1}), Atlantic salmon (2.217 mg.kg^{-1}), European seabass (1.490 mg.kg^{-1}). The lowest Zn levels in this study were found in tilapia (2.64 ± 0.22 mg.kg^{-1}) and sutchi catfish (2.03 ± 0.37 mg.kg^{-1}). These concentrations are similar to those reported by Olmedo et al. (2013) for sutchi catfish 1.274 mg.kg^{-1} and Tawell et al. (2013), who measured Zn levels in tilapia the range of 1.01 – 1.69 mg.kg^{-1}, depending on the season.

Conclusions

Fish production in the Czech Republic largely comes from growing common carp. This fish represents 85 to 88 per cent of all fish produced in the country. Nearly half of this is exported. Thus, the domestic fish market depends largely on imported fishery products. Both the domestic and imported fishery products were tested for concentrations of metals and microelements in their tissues to assess, whether they do not exceed maximum allowable levels. In the great majority of samples, concentrations did not exceed such levels indicating that virtually all imported and domestically produced fishery products are safe for human consumption.

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Table 1. List of samples

Species	Origin	Wild/Cultured	*n*
FRESHWATER FISH			
Brook trout (*Salvelinus fontinalis*)	Czech Republic	C	3
Common carp (*Cyprinus carpio*)	Czech Republic	C	8
Rainbow trout A (*Oncorhynchus mykiss*)	Slovakia	C	2
Rainbow trout B (*Oncorhynchus mykiss*)	Turkey	C	4
Rainbow trout C (*Oncorhynchus mykiss*)	Czech Republic	C	3
Rainbow trout D (*Oncorhynchus mykiss*)	Spain	C	4
Rainbow trout E (*Oncorhynchus mykiss*)	France	C	3
Sutchi catfish (*Pangasius hypophthalmus*)	Vietnam	C	23
Tilapia (*Oreochromis niloticus*)	China	C	4
MARINE FISH			
Herring (*Clupea harengus*)	FAO 27*	W	6
Mackerel (*Scomber scombrus*)	FAO 27*	W	3
Patagonian grenadier (*Macruronus magellanicus*)	FAO 41*	W	2
Pink salmon (*Oncorhynchus gorbusha*)	FAO 67*	W	3
Atlantic salmon (*Salmo salar*)	Norway	C	4
Sea bream A (*Sparus aurata*)	Greece	C	3
Sea bream B (*Sparus aurata*)	FAO 27*	W	3
European seabass (*Dicentrarchus labrax*)	Greece	C	3
Blue shark (*Prionace glauca*)	FAO 34*	W	4
Walleye pollock (*Theragra chalcogramma*)	FAO 61/81*	W	5
CRUSTACEANS			
Shrimp A (*Penaeus vannamei*)	China	C	1
Shrimp B (*Metapenaeus ensis*)	FAO 71*	W	1
Shrimp C (*Pandalus borealis*)	FAO 21*	W	1
Shrimp D (*Penaeus monodon*)	Bangladesh	C	1
MOLLUSCS			
Blue Mussels (*Mytilus edulis*)	Italy	C	1
European squid (*Loligo vulgaris*)	FAO 27*	W	3

Table 2. Fish production (tonnes/year) in the Czech Republic during the period 2005-2014

Year	Common carp	Salmonids	Tench and whitefish	Herbivourous	Carnivorous	Other	Total
2005	17804	737	288	1023	211	392	20455
2006	18006	669	278	769	205	504	20431
2007	18111	776	295	747	218	464	20447
2008	17507	815	308	980	236	549	20395
2009	17258	671	271	1010	228	633	20071
2010	17746	738	241	1071	218	406	20420
2011	18198	815	208	958	228	603	21010
2012	17972	752	184	997	227	631	20763
2013	16809	682	165	892	238	572	19358
2014	17833	692	163	779	202	466	20135

Table 3. Fishery products import to the Czech market during 2005-2014 (tonnes per year)

Year	Live fish	Fresh and chilled fish	Frozen fish	Fish filets (fresh, chilled, frozen)	Smoked and dried fish	Crustaceans	Molluscs	Total
2005	858	1291	9783	24145	1965	237	467	38746
2006	698	1360	9680	25148	1091	268	678	38923
2007	451	1836	9587	24098	1460	486	949	38867
2008	427	2857	9515	27653	1401	502	1476	43831
2009	227	1993	10213	28654	1321	624	1470	44502
2010	272	2554	8048	27092	1209	553	840	40568
2011	647	4832	6813	23600	1235	691	887	38705
2012	540	6360	7192	19293	9261	863	803	44312
2013	827	5811	7874	21735	1973	1276	1064	40560
2014	691	7169	7765	20371	1545	2098	989	40828

Table 4. Major imported fishery products in 2014 (Czech Statistical Office, 2015).

Species	Product	Tonnes
Atlantic salmon *(Salmo salar*)	Fresh/chilled whole fish and filet	8 068
Herring (*Clupea harengus*)	Frozen meat and filet	5 117
Mackerel (*Scomber scombrus/japonicus*)	Frozen whole fish	4 117
Walleye pollock (*Theragra chalcogramma*)	Frozen filet	3 530
European hake (*Merluccius merluccius*)	Frozen filet	1 876
Schrimp (*Penaeus* spp.)	Frozen whole shrimp	1 222
Sutchi catfish (*Pangasius* spp.)	Frozen filet	1 139
Total of the seven mostly imported species		25 069
Total import 2014		40 828
Percentage of the nine imported fish species		61.4

Table 5a: Concentrations of metals and microelements in tissues of freshwater fish sold in the Czech market

Species	THg (mg kg^{-1} w.w.) LOQ=0.001 mg kg^{-1}		Pb (mg kg^{-1} w.w.) LOQ=0.02 mg kg^{-1}		Cd (mg kg^{-1} w.w.) LOQ=0.002 mg kg^{-1}		Ni (mg kg^{-1} w.w.) LOQ=0.002 mg kg^{-1}		As (mg kg^{-1} w.w.) LOQ=0.02 mg kg^{-1}		Cu (mg kg^{-1} w.w.) LOQ=0.05 mg kg^{-1}		Zn (mg kg^{-1} w.w.) LOQ=0.5 mg kg^{-1}	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
FRESHWATER FISH														
Brook trout	0.033_b	0.002	$<0.02_a$	-	$<0.002_a$	-	$<0.05_a$	-	1.21_d	0.030	0.295_b	0.045	4.05_b	0.07
Common carp	0.023_b	0.024	$<0.02_a$	-	$<0.002_a$	-	0.090_b	0.021	0.061_{ab}	0.023	0.328_b	0.089	4.52_b	2.24
Rainbow trout A	0.017_b	0.001	$<0.02_a$	-	$<0.002_a$	-	0.080_b	-	0.695_c	0.025	0.305_b	0.015	4.03_b	0.41
Rainbow trout B	0.008_b	0.002	$<0.02_a$	-	0.002_a	-	0.075_b	0.025	0.325_c	0.043	0.238_b	0.048	3.11_b	0.47
Rainbow trout C	0.013_b	0.003	$<0.02_a$	-	$<0.002_a$	-	$<0.05_a$	-	0.133_{bc}	0.042	0.250_b	0.024	3.17_b	0.43
Rainbow trout D	0.036_b	0.024	$<0.02_a$	-	$<0.002_a$	-	0.075_b	0.025	0.435_c	0.309	0.255_b	0.052	3.09_b	0.25
Rainbow trout E	0.014_b	0.001	$<0.02_a$	-	$<0.002_a$	-	$<0.05_a$	-	0.423_c	0.102	0.270_b	-	3.62_b	0.36
Sutchi catfish	0.004_a	0.004	$<0.02_a$	-	$<0.002_a$	-	$<0.05_a$	-	0.072_{ab}	0.074	0.100_a	0.029	2.03_a	0.37
Tilapia	0.002_a	0.001	$<0.02_a$	-	$<0.002_a$	-	$<0.05_a$	-	0.040_a	0.022	0.133_a	0.012	2.64_b	0.224

w.w., wet weight; LOQ, limit of quantification

Table 6: Health limits (mg kg^{-1}) in the Czech Republic (Regulation (EC) No. 1881/2006)

Metal	**Fish[(a,c)]**	**Other fish[(b,d)]**	**Crustaceans**	**Molluscs**
Mercury	0.5[a]	1.0[b]	0.5	-
Lead	0.3	0.3	0.5	1.5
Cadmium	0.05[c]	0.2-0.3[d]	0.5	1.0

[a]All fish expect carnivours fish group; [b] Carnivorous fish group included following fish species: pike, sharks, tuna, swordfish, sturgeon; [c] All fish except fish with affinity to cumulate cadmium; [d]Fish with affinity to cumulate cadmium such as: European eel, sardine, mullet.

CHAPTER 4

HEAT-TREATED FISH MEAT MEAL

Nebeský, V., Levý, E., 2014. Heat-treated fish meat meal. The Industrial Property Office of the Czech Republic. Praha, Utility model No. 27240.

My share on this work was about 50%.

UTILITY MODEL

(19) CZECH REPUBLIC

INDUSTRIAL PROPERTY OFFICE

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(54) Title of the utility model:
Heat-treated fish meat meal

CZ 27240 U1

CZ **27240** U1

Heat-treated fish meat meal

Field of technology

The solution relates to the sphere of food processing industry, in particular to heat-treated meals prepared from fish meat.

Existing state of technology

Various kinds of meals, terrines, pâtés etc. are prepared from sea and freshwater fish. A significant ingredient of terrines is a high proportion of gelatine in the meal content. On the one hand, the gelatine strengthens the terrine and facilitates its storage and serving, however, on the other hand, it worsens its taste qualities.

Another disadvantage of known fish meat meals prepared on the basis of a fish meat stuffing is the fact that they contain a high amount of fat, stabilizers, colourings and preservatives or substances increasing the meal content on the basis of soya or starch. These substances not only decrease taste qualities of a product but they also worsen its overall quality because the content of fish meat is very low.

The task of the technical solution is to create a heat-treated fish meat meal which would contain a high proportion of fish meat, especially from freshwater fish, and which would contain only natural substances.

Basis of the technical solution

The task has been solved by creating a heat-treated fish meat meal on the basis of a fish meat stuffing according to the submitted technical solution. The basis of the technical solution lies in the fact that the finely ground stuffing contains at least 90% of carp meat, 5% of cream, 1% of egg matter, 1 to 2% of salt, 1 to 2% of seasoning and 1 to 2 % of fish broth. The advantage is that the fish meal according to the technical solution contains neither preservatives, stabilizers, colourings nor any substances increasing the volume.

The seasoning contains ground pepper, allspice, bay leaf, nutmeg and juniper. This combinations will add the meal its required taste qualities.

A finely ground stuffing is defined by the diameter of the grinding sieve mesh with the size of 0.1 mm. Such obtained fineness of the stuffing enables easy mixing and blending of the meal.

The fish meat meal can also contain almonds and/or dried fruit and/or pickled pepper and/or mushrooms and/or their mixture. These ingredients enhance the flavour of the product and increase its variability.

Advantages of the heat-treated fish meat meal according to the technical solution lie in a high taste quality thanks to the absence of preservatives, stabilizers, colourings and fillings on the basis of starch or soya. The product is of a high dietetic value and is suitable for a gluten-free diet.

<u>Examples of the technical solution implementation</u>

It is understood that the below described and pictured concrete cases of the technical solution implementation are introduced for illustration and not as a limitation of the technical solution for the mentioned examples. Experts knowledgeable about the state of technology will find or will be able to ensure, with the use of routine experiments, a larger or smaller number of equivalents to specific implementations of the technical solution which are described herein. These equivalents will also be included within the scope of the following claims to protection.

The heat-treated fish meat meal is made of finely ground fish stuffing from mechanically separated carp meat. The meal contains at least 90% of carp meat, 5% of cream, 1% of egg matter, 1 to 2% of salt, 1 to 2% of seasoning and 1 to 2% of fish broth.

The fish broth is a carp broth.

The carp stuffing is finely minced in a mincer with the diameter of the grinding sieve mesh of 0.1 mm.

The carp stuffing as a basis of a meal can be seasoned with almonds, dried fruit, e.g. cranberries, pickled pepper or mushrooms, e.g. field mushrooms or oyster mushrooms. It is also possible to create a mixture from the above-mentioned ingredients which is used for seasoning the carp stuffing.

The heat-treated fish meat meal does not contain any preservatives. It is filled into containers, e.g. preserving jars with reusable lids, and subsequently it is cooked in steam. The boiling time depends on the size of the container but it takes at least 45 to 50 minutes. Afterwards, the containers must be sharply cooled down in water with ice or in a device intended for shock cooling.

<u>Industrial applicability</u>

The heat-treated fish meat meal according to the technical solution can be used as diversification of meals made of fish meat and it can also become a part of diet of persons having health issues, e.g. gluten-free diet etc.

CLAIMS TO PROTECTION

1. The heat-treated fish meat meal on the basis of the fish meat stuffing is **distinguished by the fact that** the finely ground stuffing contains at least 90% of carp meat, 3 to 5% of cream, 1 to 2% of egg matter, 1 to 2% of salt, 1 to 2% of seasoning and 1 to 2% of fish broth.

2. The heat-treated fish meat meal according to claim 1 **is distinguished by the fact that** the seasoning contains ground pepper, allspice, bay leaf, nutmeg and juniper.

3. The heat-treated fish meat meal according to claims 1 and 2 **is distinguished by the fact that** the finely ground stuffing is defined by the diameter of the grinding sieve mesh with the size of 0.1 mm.

4. The heat-treated fish meat meal according to at least one of the claims 1 to 3 **is distinguished by the fact that** it also contains almonds and/or dried fruit and/or pickled pepper and/or mushrooms and/or their mixture.

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CHAPTER 5

MARINADE, PARTICULARLY FOR PREPARING FISH MEAT

Nebeský, V., Levý, E., 2015. Marinade, particularly for preparing fish meat. The Industrial Property Office of the Czech Republic. Praha, Utility model No. 28153.

My share on this work was about 50%.

UTILITY MODEL

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(54) Title of the utility model:
Marinade, particularly for preparing fish meat

CZ 28153 U1

Industrial Property Office does not investigate within the registration proceedings whether the subject matter of the utility model fulfils the eligibility conditions for protection according to Section 1 of Act No. 478/1992 Coll.

CZ **28153** U1

Marinade, particularly for preparing fish meat

Field of technology

The technical solution relates to the sphere of culinary art, in particular to a marinade which is designated mainly for cold preparation of fish meat.

Existing state of technology

Fish meat is an easily digestible foodstuff containing very important substances for human organism. It is of a characteristic smell and taste due to which it is not very popular with some consumers. There are different fish meat preparation methods, such as cooking, frying or grilling.

Sea fish and salmon are often consumed cold marinated in a brine or in various marinades. Preparation of fish meat is thus very easy and fast and, at the same time, it is sound and enables preservation of healthy substances in fish meat.

For example, Gravad Lax is a very popular Nordic dish consisting of raw salmon cured in salt, sugar and dill. Such marinated meat matures for two to three days before consumption.

The task of the technical solution is to create a marinade for cold consumption of fish meat, especially of freshwater fish, without using preservatives.

Basis of the technical solution

The task has been solved by creating a marinade according to the submitted technical solution. The marinade which is intended particularly for preparing fish meat contains sugar and salt as its basic ingredients. The basis of the technical solution lies in the fact that it also contains lemon juice, lime juice and orange juice in a mutual ratio of 1:1:1. The combination of these citrus juices increases nice smell of fish meat. It also helps to rid the meat of its typical fish smell which is perceived negatively by some consumers. In addition to that, citrus juices have preservative effects.

The marinade contains 300 g of sugar, 300 g of salt, 100 ml of lemon juice, 100 ml of lime juice and 100 ml of orange juice. The marinade composition is very simple and cheap. The marinade can be easily prepared both at home and in restaurant facilities. The marinade contributes with its pleasant and aromatic taste to an increase in popularity of freshwater fish meat.

The advantage of the marinade according to the submitted technical solution is that it contains neither preservatives nor stabilizers and it significantly increases tastiness of cold consumed freshwater fish meat.

Examples of the technical solution implementation

It is understood that the below described and pictured concrete cases of the technical solution implementation are introduced for illustration and not as a limitation of examples of the technical solution for the mentioned examples. Experts knowledgeable about the state of technology will find or will be able to ensure, with the use of routine experiments, a larger or smaller number of equivalents to specific implementations of the technical solution which are described herein. These equivalents will also be included within the scope of the following claims to protection.

1 kilogram of carp dorsal muscles is to be marinated in the marinade prepared from 300 g of table salt, 300 g of sugar, 100 ml of lemon juice, 100 ml of lime juice and 100 ml of orange juice.

Carp meat is to be thoroughly smeared with the marinade, put into a container inside which a vacuum will be created. The vacuum value is of -1 MPa. Marinating in the vacuum lasts 6 hours.

After removal from the vacuum container, the muscles are to be cleaned, dried and coated in the seasoning mixture. In this implementation example the seasoning mixture contains ground pepper, dried dill and dried fennel. The amount of the seasoning mixture represents 1% of the total muscle weight. Such treated carp dorsum is to be placed back in the vacuum of -1 MPa value and it is left to mature at 4°C for 72 hours.

Finally, the carp dorsal muscles are cut into slices with the thickness of 0.5 mm.

Industrial applicability

The marinade intended particularly for preparing fish meat according to the submitted technical solution can be used for preparation of fish meat at home or in restaurant facilities.

CLAIMS TO PROTECTION

1. The marinade intended particularly for preparing fish meat containing sugar and salt is **distinguished by the fact that** it also contains lemon juice, lime juice and orange juice in a mutual ratio of 1:1:1.

2. The marinade according to claim 1 is **distinguished by the fact that** it contains 300 g of sugar, 300 g of salt, 100 ml of lemon juice, 100 ml of lime juice and 100 ml of orange juice.

End of the document

CHAPTER 6

WHOLE FISH TAXIDERMY

Nebeský, V., Bláha, M., 2012. Whole Fish taxidermy. Edition of Manuals No. 125, FFPW USB, Vodňany, 38 pp.

It was allowed by publisher on 20th April 2017 to include the paper in this Ph.D. thesis.
My share on this work was about 90%.

FACULTY OF FISHERIES AND PROTECTION OF WATERS

UNIVERSITY OF SOUTH BOHEMIA IN ČESKÉ BUDĚJOVICE

WHOLE FISH TAXIDERMY

V. Nebeský, M. Bláha

Vodňany

2012

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Edition of Methodologies No. 125

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TABLE OF CONTENTS

1. AIM OF THE METHODOLOGY

The aim of the methodology is to familiarize readers with basic procedures and principles to be able to prepare a permanent mount of a whole fish. The methodology will find its use primarily in domestic production fishery enterprises where it can help treating dead fish which are no longer suitable for further processing for human consumption. In this way, it is possible to ensure an interesting appreciation of depreciated material which would otherwise end up in a rendering plant. The methodology can also help sport anglers and members of fishery unions with mounting and preserving their trophy catches.

2. DESCRIPTION OF THE METHODOLOGY

The methodology details the entire production process of fish mounts intended for the future sale as decorative or teaching material. The methodology provides a time-tested procedure for taxidermy of whole fish.

2.1. Current techniques

Fish taxidermy involves an array of possible methods and procedures. The simplest procedure represents desiccation without using any chemicals. However, such a mount corresponds neither to its original shape nor colour and additionally it has a short lifetime. If we keep a fish before the desiccation itself in an alcohol or formaldehyde solution for a particular time, its lifetime will be extended and a visual result will be similar. In order to keep the original shape, it is necessary to remove all soft tissues and replace them with material which will not change its volume over time. For this purpose, sawdust combined with various additives and their combinations (plaster, polystyrene, glues etc.) are used the most often. Some modern technologies use a mould made of special materials from which a fish body is pre-modelled and subsequently covered with the fish skin. In order to remove water from tissues, a classic desiccation by means of higher temperature and air blast is used the most frequently. A very gentle method for mount desiccation is a method referred to as vacuum freeze-drying or lyophilisation. A low temperature and pressure are used in a special apparatus which causes the sublimation of frozen water. This drying method in connection with the mould is used for example by the Austrian Hofinger Tierpräparationen Company.

Application of any mounting method causes loss of the original skin colour. On that ground it is necessary to paint the fish. There are again several different techniques how to achieve the original colour. The most common way is the use of brushes and oil or acrylic paints and subsequent painting with clear varnish. The most ideal result can be achieved by the application of the colours by spraying; it is so-called airbrushing, through which it is possible to achieve almost perfect colouring of even the smallest details (Hall and Saxton, 1987).

Articles in the Fishery magazine from the beginning of the 1990s can be considered the most comprehensive procedure for mounting whole fish and fish heads published so far in the Czech Republic (Pelikán, 1991, 1992). The author of the procedure called “Mounting of fish trophies” was a taxidermist Petr Pelikán.

An individual way is represented by making so-called fish replicas which are prepared in special moulds. The obtained cast is subsequently rearranged and retouched according to a photograph to take appearance corresponding to the original (Advanced Wildlife Design, 2012).

2.2. Preparation of the material for the mounting

A fish to be mounted should ideally be recently dead or killed without any serious damage on its skin surface or fins. Such fish, however, are not always available or, on the other hand, there is suddenly a large number of dead fish available due to a mass death. For the mounting purposes, it is possible to use even dead fish but everything depends on their state and level of damage.

In order to assess whether a fish is suitable for mounting or not, at least minimum experience is required. As a matter of fact, there is a great number of different decisive factors. Nevertheless, the main determinant is water temperature that designates the speed of chemicals as well as biological processes inside and outside the dead fish body. Basically, it can be generally stated that if the fish gills are at least light pink, it is possible to use the fish for mounting without any major troubles.

As far as recently dead or killed fish are concerned, rigor mortis usually occurs within several tens of minutes depending on a species, temperature, level of stress and other factors. Biochemical processes and ripening of meat occurs in the fish muscles. Mounting at this stage is not suitable, mainly due to difficult manipulation. At the last stage before rigor mortis occurs, the fish is stiff and tensed and usually bent. Such bending is typical mainly for fish with a larger body which were suffocated during pond harvests due to a lack of dissolved oxygen or water turbidity. If possible, it is advisable to make a photographic documentation (Fig. 1) of the fish intended for mounting in order to capture its colours and drawing which usually almost disappear during the mounting process. Afterwards, it is possible to make the final visual colour appearance according to the photographs of a particular piece.

If it is impossible to do the mounting immediately due to time reasons, it is possible to freeze the fish.

Fig. 1. *Capturing the original colour of the fish which is to be mounted.*

2.3. Preparation for freezing

It is possible to freeze whole fish with their internal organs, gutted or in a form of a semi-finished product fully freed from the guts and muscles. In case of a long-term and unsuitable storage of frozen material, there is a threat of its freezing out (sublimation of water from fish body), breaking off of the fins or commencement of fats and proteins decomposition. Therefore, the freezing process must be paid maximum attention to and certain principles must be followed.

Before the freezing itself, the fish must be hermetically wrapped up in a plastic bag so that the bag fits tightly to the skin (Fig. 2). At this stage, the fins must also be firmly pressed towards the body. Caudal fins usually cause troubles as these are often damaged during the freezing. It has proved useful to place the fin into the clips from a non-absorbent material, e.g., an office PVC board. Such treated fins endure even a possible manipulation in a frozen state. In no case it is recommended to freeze more fish all together. When later attempted to detach individual fish from each other, they often become damaged. The same procedure can be applied with partially gutted fish, which means fish with removed guts (primarily the digestive tract).

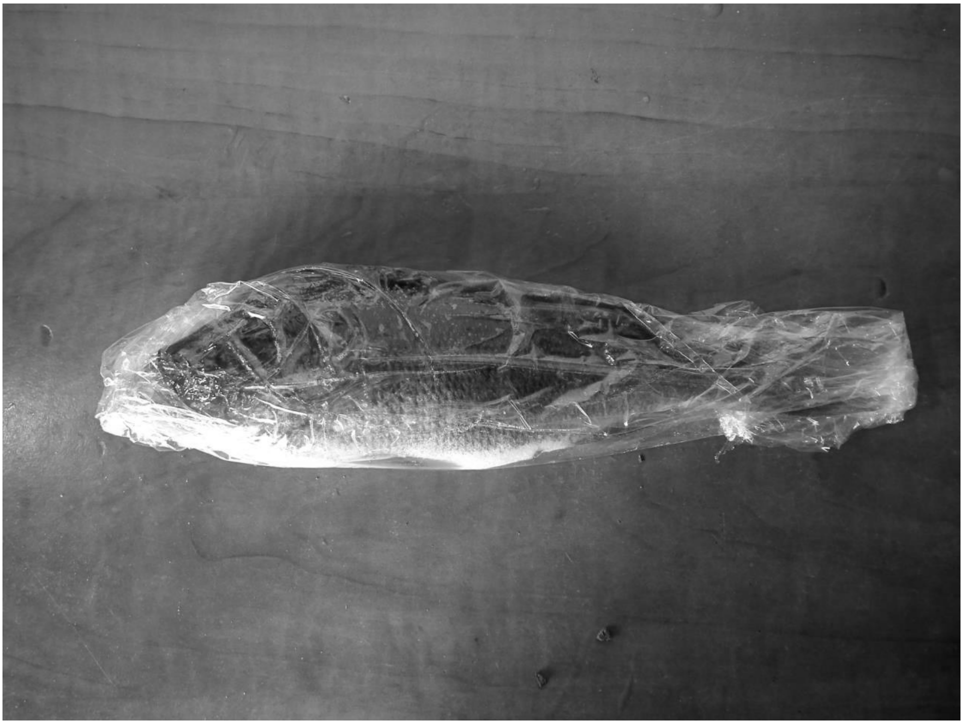


Fig. 2. *Fish prepared for freezing with its body tightly covered with a plastic bag and non-protruding fins.*

It is advantageous to freeze individual flayed skins as it saves space in freezing equipment; however, these skins are very prone to various damage as well as freezing out. Skins must be frozen in an outstretched original position and any bend could cause pulling the scales out of the sockets or even to fall out. It must be pointed out that this method is mainly suitable for percoids and salmonids whose scales are smaller and firmly embedded. As far as other fish species are concerned, skin can be damaged by scales falling out.

In case of freezing whole, especially piscivorous fish, longer-term storage can lead to probable digestion of guts through the activity of proteolytic enzymes contained in the stomach and guts. Such damaged tissues make the removal of the muscles more difficult during the mounting itself and in the worst-case scenario, it can lead up to fish skin damage. Species such as pike-perch or pike where this danger is real are advisable to be processed as soon as possible (in weeks) since the freezing. It has proved very useful to partially gut the fish and remove the guts already before the freezing. However, placement of the section on the fish side and its subsequent putting on a board must be decided in advance.

2.4. Unfreezing the material

Unfreezing the fish or a semi-finished product (skin) is recommended to be carried out as fast as possible (Fig. 3). The best way of unfreezing the fish is to put it in a tank containing tepid water (20 – 25 °C) and the fish should be fully submerged so that the muscles unfreeze evenly. Under no circumstances is it recommended to carry out slow unfreezing at the room temperature or in a refrigerator. During such unfreezing, activity of proteolytic enzymes in the fish guts is set off and microorganisms on the fish surface and mainly the gills start to develop. At the same time, it can cause possible drying off of the fish body surface and fins.

It has proved useful not to unfreeze the fish wholly but only several millimetres deep (3 – 6 mm). The fish in this state is easier to be handled because muscles of the unfrozen fish are usually disrupted and soft and leaving the fish in a partially frozen state enables easier manipulation and work with a surgical knife.

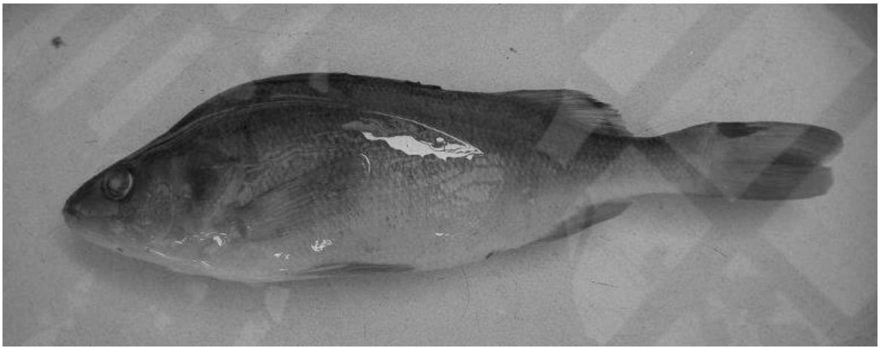


Fig. 3. *Unfreezing the fish in a water bath*.

2.5. Arrangements for the mounting itself

Before initiation of the mounting itself, it is necessary to prepare the work surface, instruments and chemicals. Later gathering of the working aids after the mounting process has been initiated could endanger the entire outcome, primarily due to possible drying of the scales and fins.

Close attention must be paid to a worksite. It should be well-lit within its entire surface. It is also required to ensure exhaustion of smell and fumes of formaldehyde that will be used as a fixation agent for protein denaturation. These conditions are best fulfilled by a laboratory fume cupboard. If a fume cupboard is not available, work can be carried out in a well-ventilated room. A work mat should be made of a soft material (e.g. soft foam) which will adapt to a fish shape during the entire process and which will also maintain wetness to prevent the fish body surface from becoming dry. In order to achieve a better contrast, the photographs in this publication were taken on a white surface. The size of the mat must be larger than the fish itself.

At this moment it is necessary to plan a final form of the mount and also to choose the side of the fish where the cut through which the muscles will be removed from the body will lead through. This side of the finished mount will then be hidden by the board to which it will be attached to.

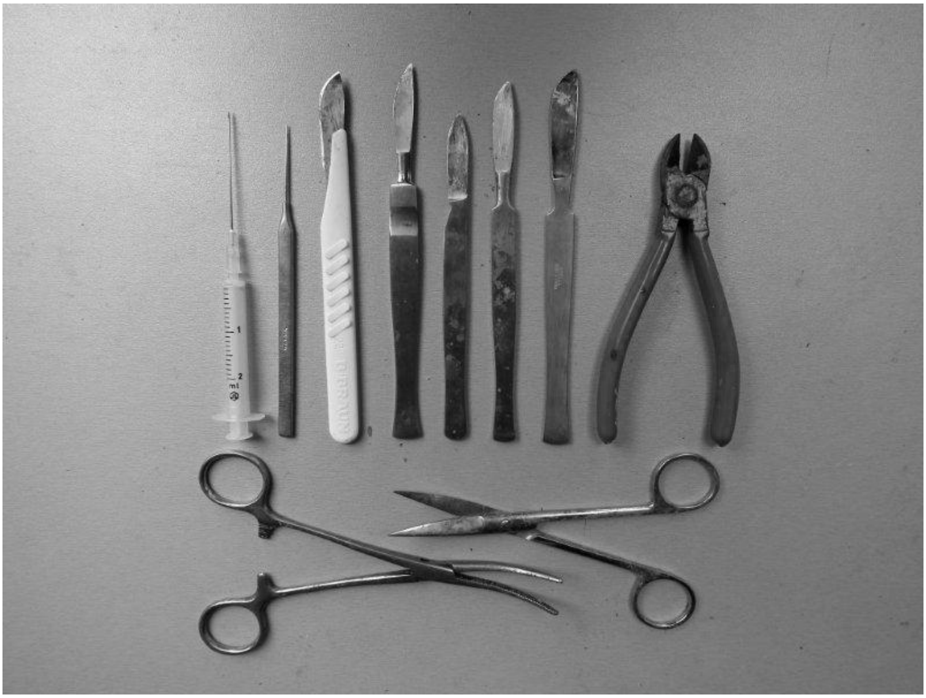


Fig. 4. *A set of basic mounting tools.*

2.6. Removal of muscles from the fish body

Required aids for this stage (Fig. 4):

surgical knife

pairs of tweezers

haemostat

preparation needles

foam mat

water sprayer

8% formaldehyde solution

bowls

surgical gloves

The fish is to be carefully placed on a damp mat and the main section is to be performed on the side of the fish leading from the base of the caudal fin to the opercular bone (Fig. 5). With regard to fish with fine skin and small scales, the section can be carried out with a surgical knife. As far as other fish are concerned, it is advisable to use surgical scissors that can cut even hard scales.

Fig. 5. *The main section on the side of the fish*.

After that, the muscles are to be separated from the skin by gentle pulling and at the same time, they are to be removed from the body by means of a pair of tweezers and a haemostat (Fig. 6 and 7). Since sharp instruments are used, it is necessary to proceed very carefully and not to cut the skin.

Fig. 6. *The skin is carefully detached from the muscles*.

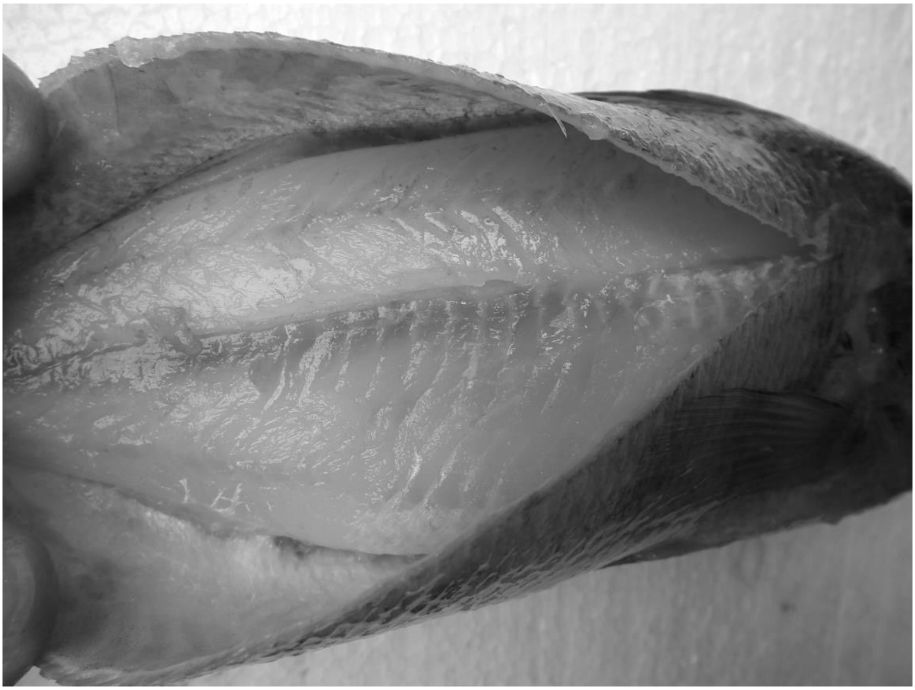


Fig. 7. *The skin detached from the muscles on one side*.

In order to cut the bones or the backbone, it is necessary to use pliers (Fig. 8). By means of these tools we will roughly remove the muscles, internal organs, backbone and bones from the body. This stage results in a flayed fish – the skin with the scales, fins and the head (Fig. 9).

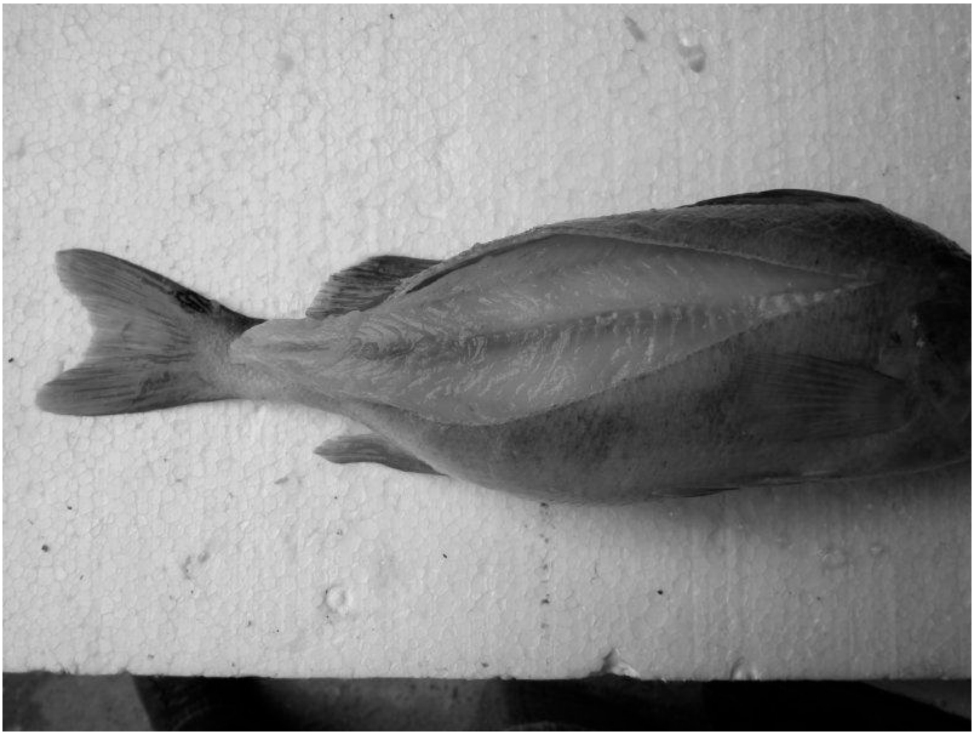


Fig. 8. *In order to break the backbone in the caudal part, it is suitable to use pliers*.

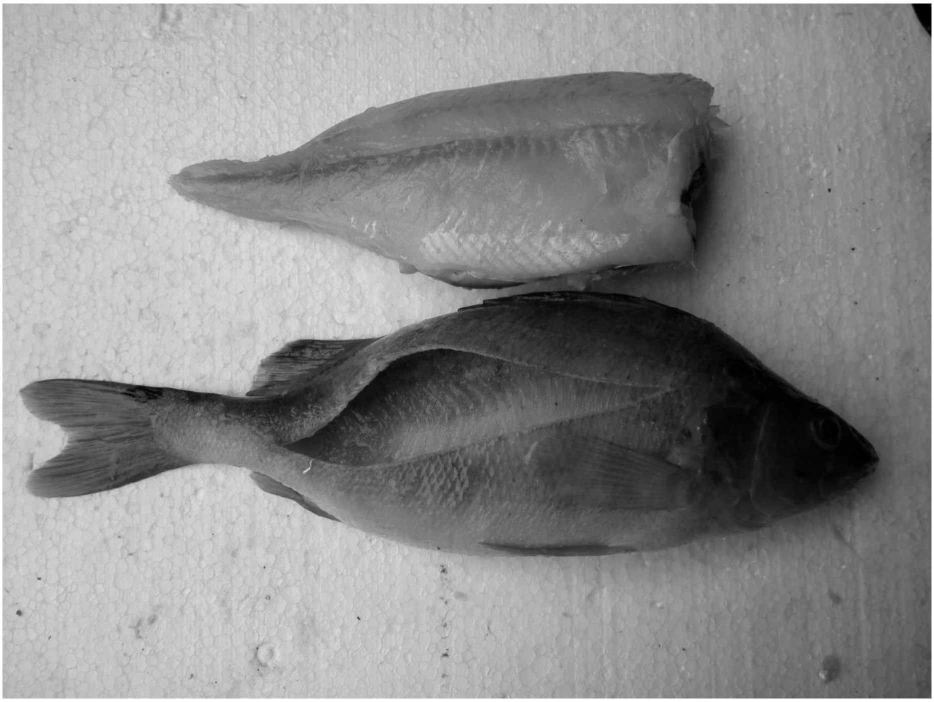


Fig. 9. *The fish body and the skin and fins before final cleaning from the muscles.*

Fig. 10. *Finally prepared fish skin for the next mounting stage*.

Throughout the entire time of the muscles removal, it is advisable to moisten the fish and fins surface with water by means of a sprayer. After this stage, it is required to finish cleaning of the skin from the last remains of the muscles and possible removal of the fat layer (Fig. 10).

Fig. 11. *The last step of this stage is represented by removal of soft tissues from the head.*

It is also necessary to remove the muscles and other soft tissues, such as the eyes and the brain, from the fish head (Fig. 11). The muscles from the cheek parts of the head are to be removed through the eye sockets by means of a scalpel and a longer haemostat or a pair of tweezers. With regard to a very fine skin which is situated here, it is required to pay increased attention when using sharp instruments. With regard to smaller fish whose opercular bones will not be opened, it is advisable to cut off the branchial rods or alternatively wholly remove the branchial archs. This will enable better subsequent drying of the mount. As far as larger fish are concerned, it is advisable to leave their branchial archs inside the body.

Now it is time to wash the whole fish with water, leave it to drain and place it in a vessel containing an 8% formaldehyde solution. The vessel should correspond to the fish size so that the whole fish is submerged in the solution (Fig. 12). In no case the skin or the fins are to be bent because the scales could come loose. The time of the formaldehyde solution bath ranges from 30 to 120 minutes depending on the fish size.

Fig. 12. *The fish skin must be wholly immersed in the formaldehyde solution to ensure its perfect preservation.*

2.7. Stuffing the mount

Required aids for this stage:

clean and sifted sawdust

modelling plaster

water

container for blending the filling mixture surgical needles

packthread

scissors

haemostat

soft foam mat

water sprayer

surgical gloves

When the fish is taken out from the formaldehyde solution, it is necessary to wash it in clean water. At the same time, we will prepare a filling mixture made of fine sawdust (Fig. 13) and plaster. We will add water to sawdust in a vessel in such a way that the sawdust remains loose after mixing (Fig. 14). Afterwards, we will add plaster in a ratio of 2 : 10 (plaster : sawdust). The result is a moist mixture which does not relieve water when squeezed (Fig. 15).

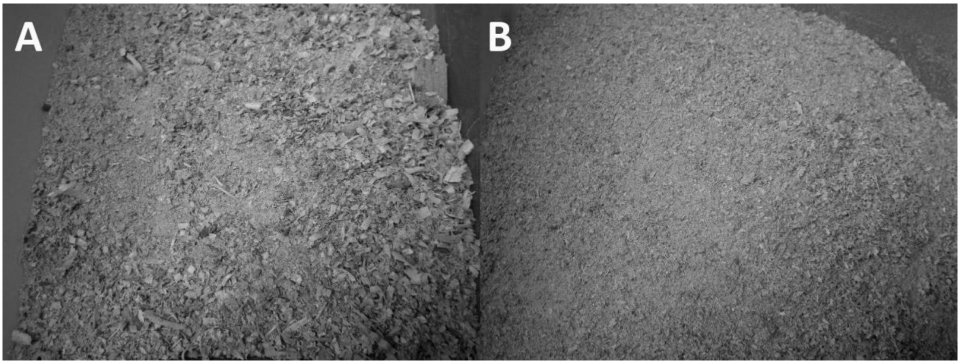


Fig. 13. *Coarse sawdust (A) must be sieved in order to get fine sawdust (B) suitable for the filling mixture with plaster*.

Fig. 14. *Sawdust remains loose even after moistening*.

Fig. 15. *Finished loose filling mixture made of fine sawdust and plaster*.

Due to evaporation of formaldehyde (it is classified as a possible carcinogen) from the fish body surface during this stage, it is advisable to work in a fume cupboard with air exhaust or in a well-ventilated room. It is also necessary to use latex gloves which will prevent direct contact of the hands with the fish body surface.

Cleaned fish should be placed on a damp soft foam mat and the first 2 to 3 stitches with a thread (Fig. 16) will be carried out. After that, we will fill this part with a filling mixture and tamp it gently down. Another 2 – 3 stitches follow and the whole procedure is to be repeated. The fish skin tends to be very delicate and is prone to be cut through with the thread (Fig. 17). It is recommended to start the sewing up of the body from the tail and continue along the section towards the head where the filling and sewing will be finished.

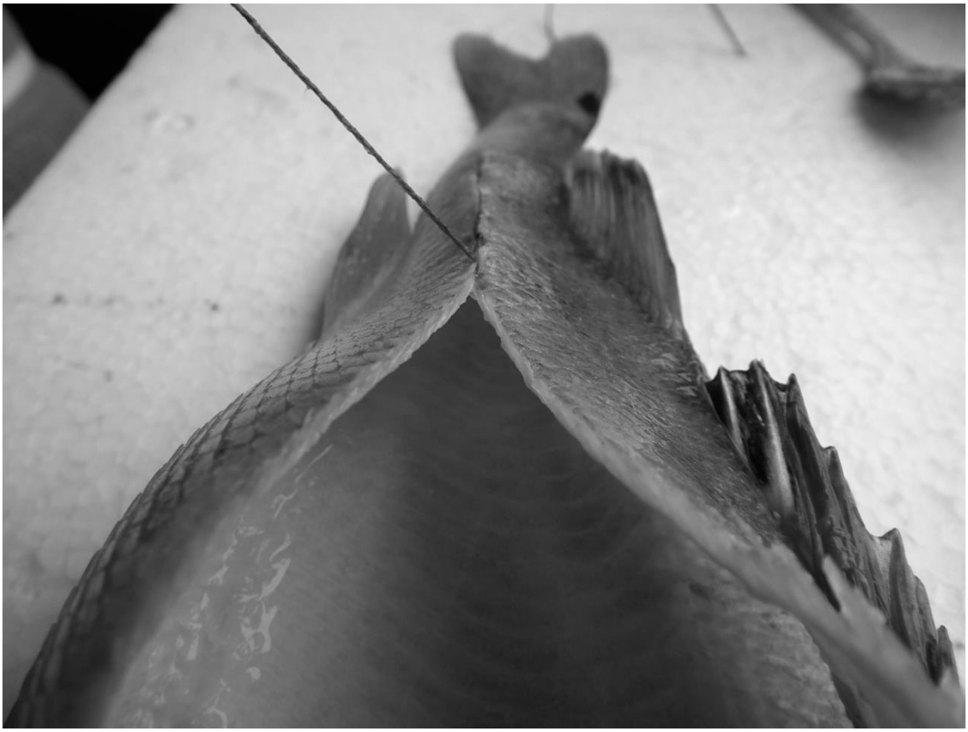


Fig. 16. *After 2 – 3 stitches, it is possible to start filling the fish with the mixture*.

Fig. 17. *The fish skin is rather delicate and the stitching must be performed very carefully*.

The mixture solidification occurs approximately after 60 – 180 minutes depending on the type of plaster used and its ratio with the sawdust. The fish is to be evenly stuffed from the tail and the stitches are to be simultaneously performed. After each 2 – 3 stitches, we are to add the mixture and tamp it down (Fig. 19).

At this stage, it is required to proceed very carefully and with delicacy and the new shape of the fish body is to be regularly modelled (Fig. 18). In case that we use an insufficient amount of the filling mixture or it is improperly tamped down, there will be sink marks on the fish body. On the other hand, if the fish is stuffed with too much mixture, it will look unnatural and puffed out.

Fig. 18. *The new fish body shape is to be modelled very gently.*

Fig. 19. *The fish is to be gradually stuffed, the shape is to be adjusted and the stitches are to continue towards the head.*

After finishing stuffing the fish body, the cheek part of the head remains. This part is to be stuffed through the eye holes and the mixture is to be tamped down again and adjusted to a required shape (Fig. 20).

Fig. 20. *Soft tissue cavities on the head must also be stuffed with the mixture. It is necessary to pay attention to keeping a natural shape.*

Before proceeding any further, it is required to clean the fish body surface and wash it with water from the filling mixture. It very often stays both on the fish body surface as well as inside the oral cavity, under the operculum and on the base of the fins (Fig. 21).

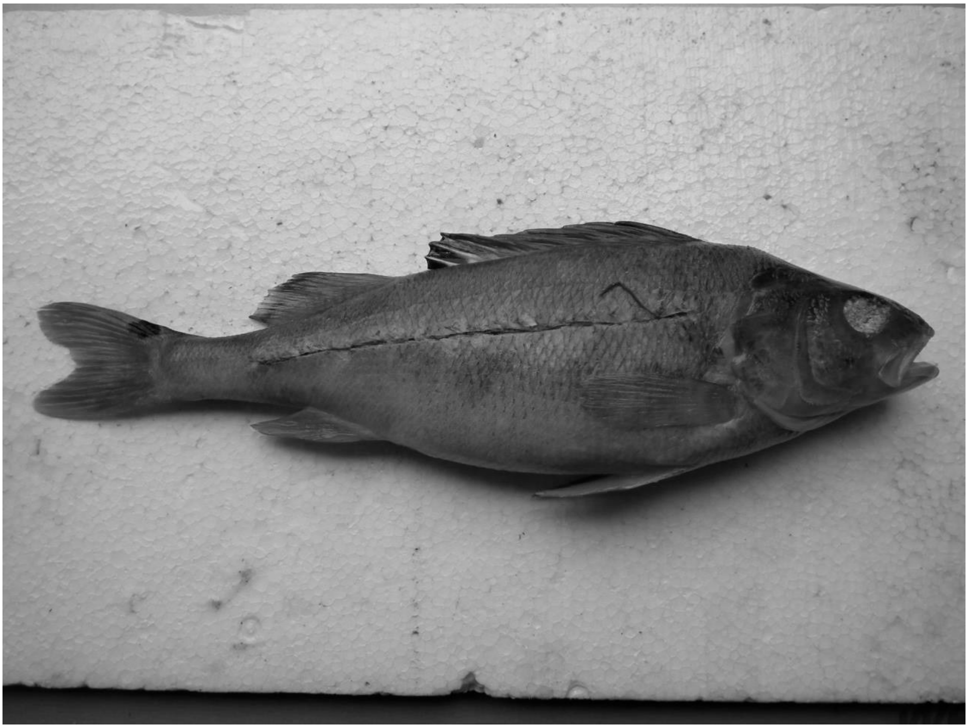


Fig. 21. *After finishing the stuffing stage, the fish body surface must be washed and all remains of the filling mixture removed.*

2.8. Preparation for the mount desiccation

Required aids for this stage:

waxed cardboard

pair of scissors

paper clips

soft foam mat

water sprayer

surgical gloves

After perfect cleaning, it is to be proceeded to fixing the fish and fins shape into a required final shape in which the mount will be desiccated. With the main section we have selected the side with which the mount will be attached to the board. The mount will be placed on this side throughout the entire subsequent process (Fig. 22).

Fig. 22. *State of the fish before fixation of the fins.*

In order to fixate the fins, we will use waxed cardboard which will be double cut out according to the size of a particular opened fin (Fig. 23).We will insert the stretched fin between the cardboard sheets and attach it with paper clips (Fig. 24). Waxed cardboard will prevent immediate sticking of the fin onto the surface, but it does not hold back gradual desiccation. In this case it is also suitable to keep the fins which have not been fixated yet into the cardboard sheets moistened by means of a water sprayer. In this way, we will fixate all paired as well as unpaired fins of the mount (Fig. 25).

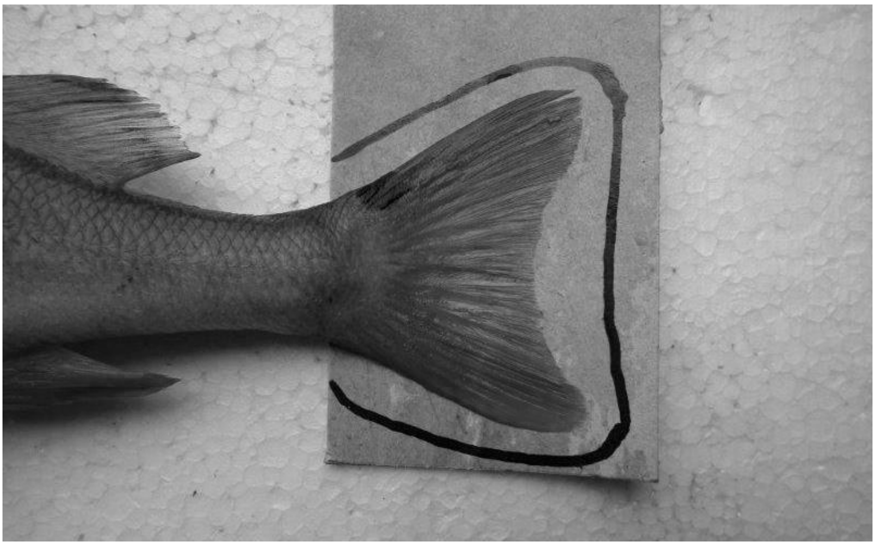


Fig. 23. *Cardboard sheets intended for fixation are to be prepared individually for each fin.*

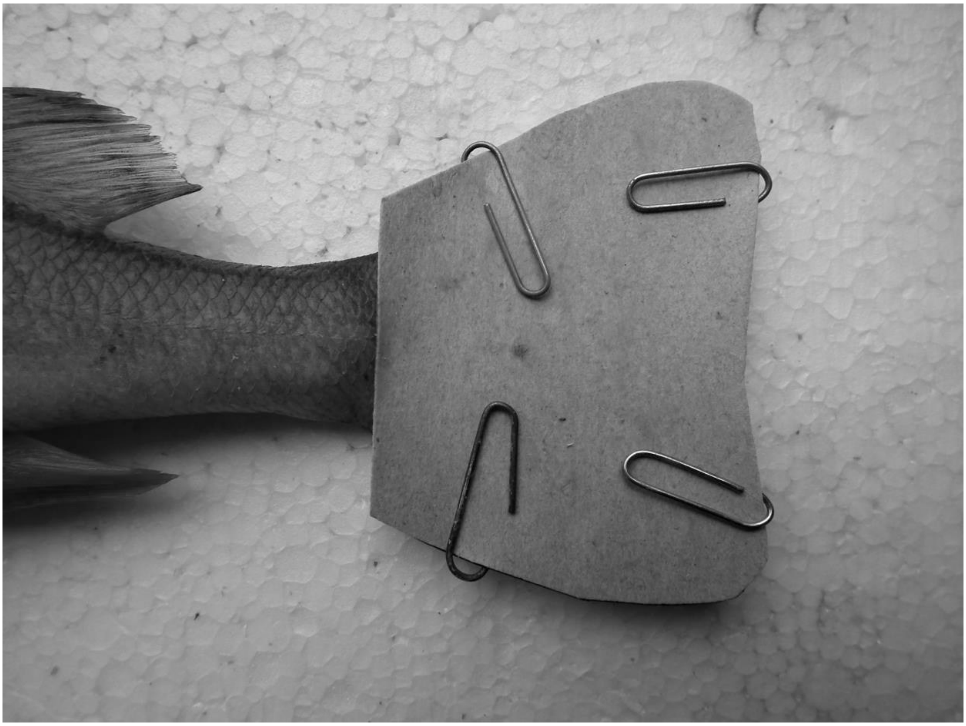


Fig. 24. *Paper clips are suitable to fixate the cardboard sheets.*

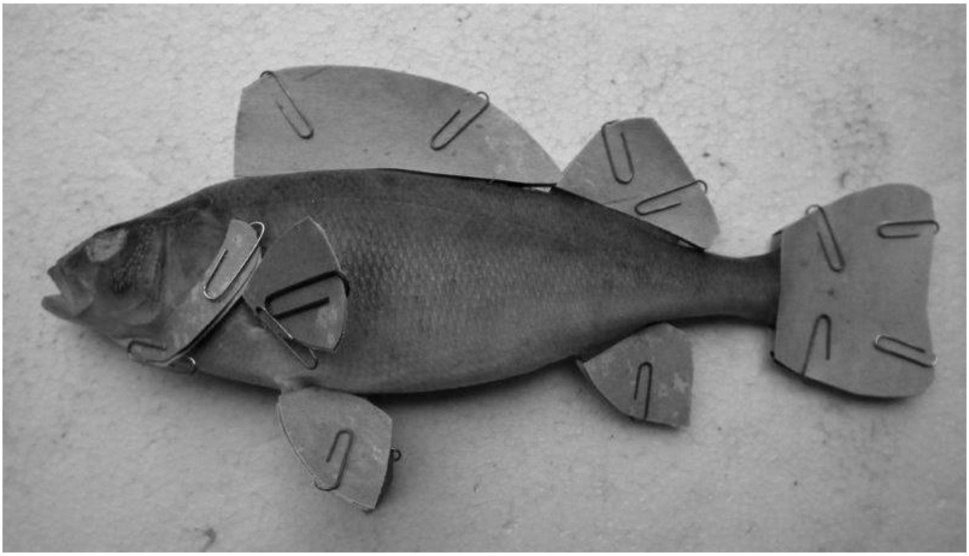


Fig. 25. *A semi-finished mount with fixated fins and the opercular bone.*

In addition to the fins, it is also required to open the fish jaws which are to be fixated in a selected angle. The last activity during the preparatory stage is putting the fish in a desiccation place and arranging it into the final shape which the mount will have after its desiccation (Fig. 26). The shape is to be chosen according to the purpose of the mount. For teaching purposes, it is better to leave the mount in a straight position so that all typical features of a given fish species can be distinguished. If the mount is a trophy intended to present the catching experience, it is appropriate to give the fish a dynamic shape in a form of a natural bent.

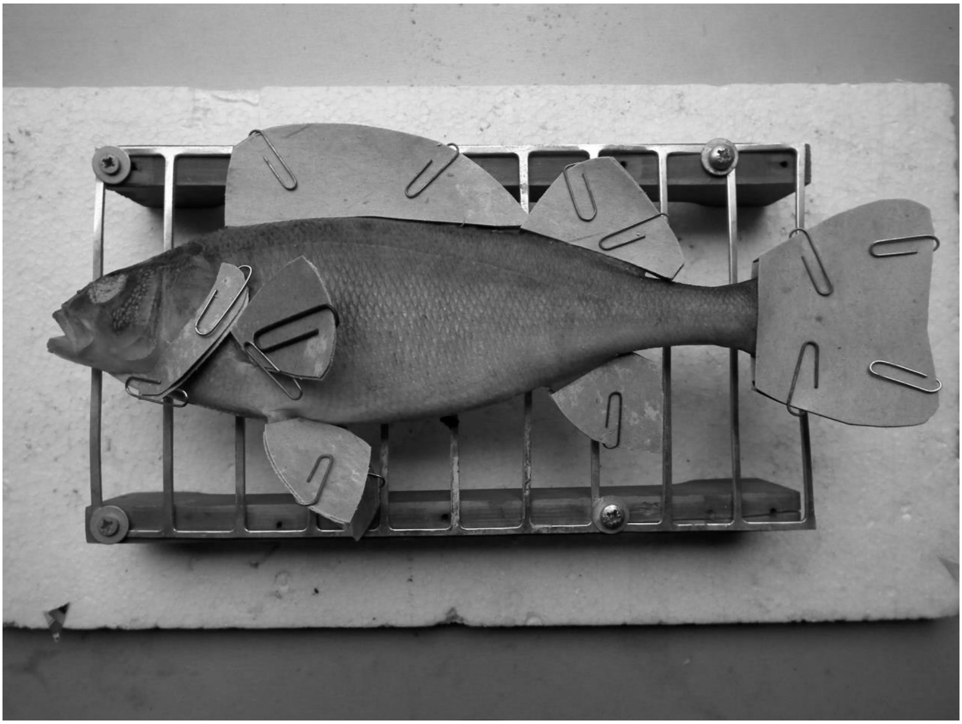


Fig. 26. *Final shape of the fish which is kept in such a way so that air circulation around the entire body is ensured.*

2.9. Desiccation of the mount

Removal of the moistness from the mount represents a crucial stage which must not be rushed. The usual desiccation time depends on the mount size and lasts approximately weeks to months.

In order to achieve good desiccation conditions, it is necessary to ensure a suitable dry place with sufficient air circulation and temperature ranging from 20 to 30 °C. If these conditions are not observed, mould can start growing in the oral cavity and on the body surface. In no case can the desiccation take place in residential parts of buildings because evaporation of not only water vapour but also formaldehyde which was used for denaturation of proteins contained in the mount takes place during the process.

2.10. Cleaning and adjustment of the mount

Required aids for this stage:

surgical knife

emery paper – (grain size no. 100)

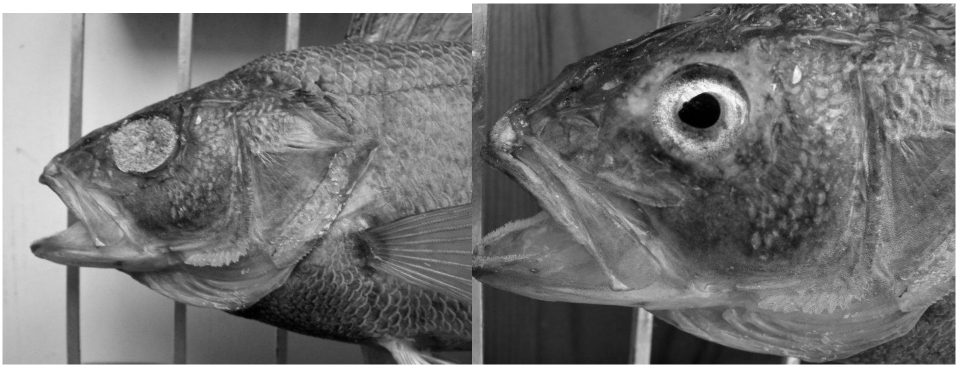
beeswax

glass eyes

After the desiccation is finished, it is time to inspect the mount and retouch possible imperfections which the fish had before initiation of the mounting or which occurred during any stage of the mount preparation.

Fig. 27. *The mount after the finished desiccation stage and with removed fixation cardboard sheets*.

We remove the cardboard sheets and the clips from the fins and clean the entire body surface by means of a soft brush (Fig. 27). Little wounds caused by possible cuts with a scalpel or fallen out scales can be neatened with the use of beeswax. Detached scales and other protrusions should be gently cut off with a scalpel and subsequently grinded with the emery paper. The eye sockets must also be cleaned off from the filling mixture and possible unevenness and then they are filled with the beeswax (Fig. 28.A) into which coloured glass eyes in a corresponding size are carefully sunk (Fig. 28.B).



A B

Fig. 28. *Detail of the head before (A) and after placing the coloured glass eye (B).*

In addition to the most commonly used glass eyes with a black pupil (Fig. 29) it is possible to use ready-made eyes offered by foreign manufacturers which can be bought in different sizes in a required shape and iris coloration according to a fish species (Fig. 30).

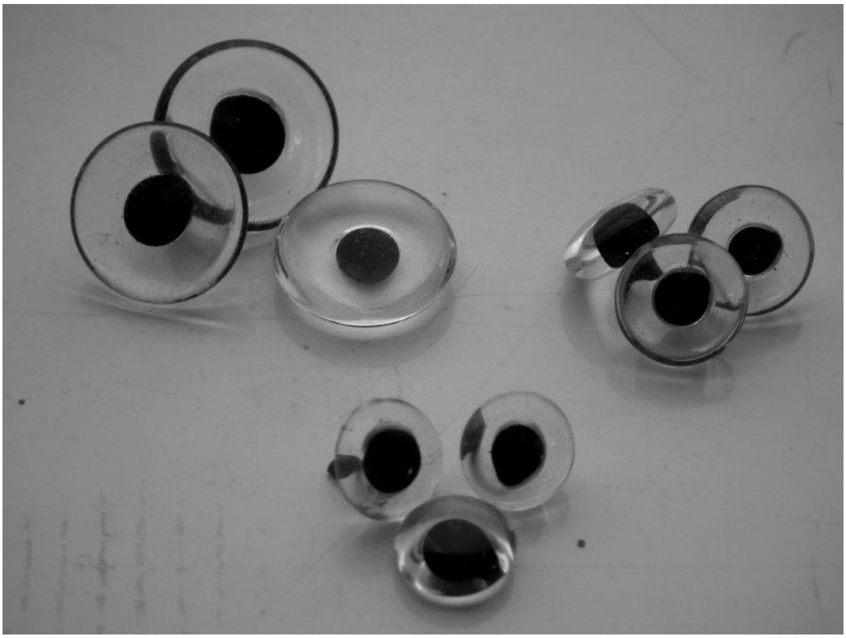


Fig. 29. *Different sizes of crystal fish eyes with an oval pupil which must be coloured in according to a fish species.*

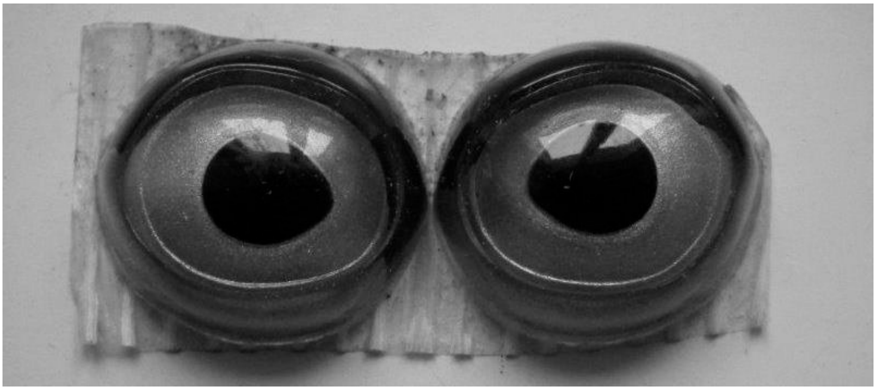


Fig. 30. *Eyes produced abroad are of a better shape and colour.*

2.11. Colouring in the mount

Required aids for this stage:

oil paints

brushes

solvent for oil paints

wooden palette

clear varnish

Fig. 31. *Different types of brushes (A) and oil paints (B) are used for colouring in the mount.*

Colouring in the mount represents one of the critical stages of the entire mounting process. Selecting an unsuitable method or paints can easily destroy the whole mount. These works are advisable to be first tried out on paper because these not only require practice but also a certain amount of artistic feelings and skills.

Oil paints are the most suitable for colouring in the fish (Fig. 31.B) as these adhere to the fish surface very well. Their advantages lie in light-fastness, covering power, colour range, long-term resistance to cracking and they are also very easy to be mixed together. Terpentine or various kinds of drying oils (linseed, walnut etc.) are used for the paint thinning. Flat and round brushes intended for oil painting (pig bristles or synthetic hair) are used for application of the paints (Fig. 31.A). Oil paints are stirred and mixed on the palette – a wooden palette with a thumb hole is suitable.

As a pattern for colouring in the mount, it is recommended to use the photograph of the live fish which was taken at the beginning before freezing the fish. Only with the photograph we are able to capture all colours and their shades (Fig. 32). Work must be carried out only during daylight. Artificial light could distort the mixed colours.

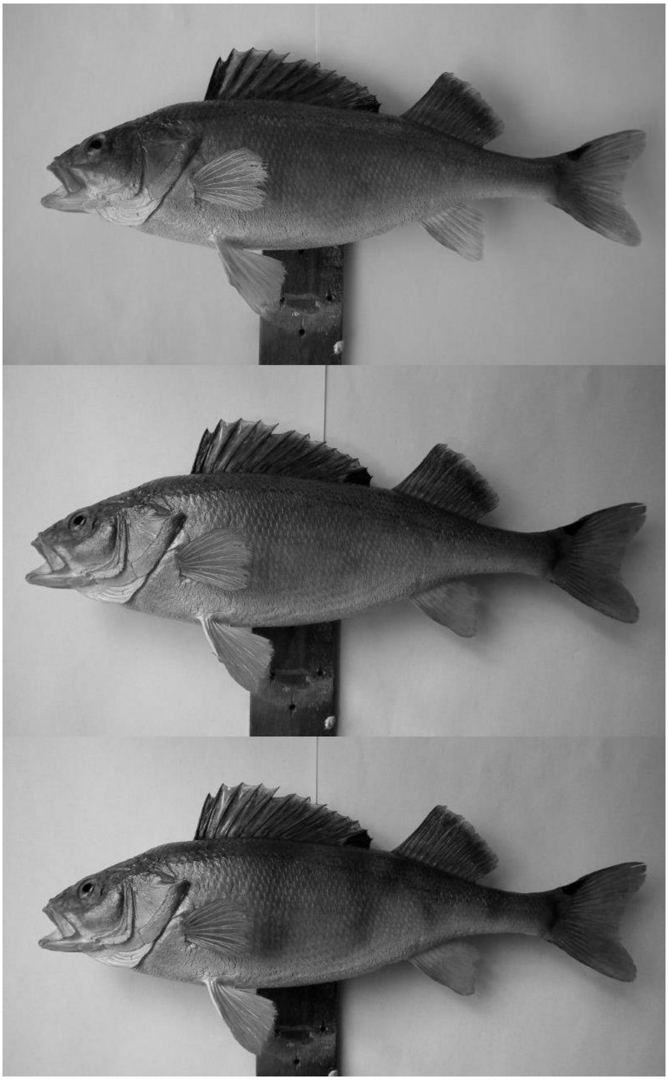


Fig. 32. *Stages of gradual colouring and putting the finishing touches to the mount.*

After finishing colouring in of the mount, it is necessary to put it again in a place with sufficient air circulation and temperature from 20 to 30 °C where oil paints will sufficiently desiccate. Depending on the type of used technology and oil, it takes approximately 7 to 14 days. We must always make sure that the paints are perfectly dry. After that, we will thoroughly clean the mount with air blast and cover it with a clear mat or semigloss varnish intended for oil paints. We should work in a dust-free environment and we should try to apply an even layer of varnish. The coat of varnish should be left to perfectly dry according to the instructions.

2.12. Attachment of the mount

Required aids for this stage:

suitable wooden board or root

brush

clear varnish

screws

The fish mount prepared in such a way must now be attached to the board on which it is to stand or hang (Fig. 33). For this purpose, two methods can be applied. The first method is attaching it onto a wooden board obtained by a cross-cut saw from a tree trunk including bark (pine or birch tree). The board should be 2 – 4 cm thick, coming from a dry wood, planed smooth on both sides, filed off and covered with a clear varnish. According to one's own taste, it is also possible to use carved wooden boards. Another method is represented by using suitable tree roots which were submerged under the water for some time and which gained a typical colour and surface structure. Roots must be properly cleaned and painted with a clear varnish before their usage.

To attach the mount to the board, we will use corresponding wooden screws in such a way that the fish is penetrated by the longest part of the screw but at the same time no damage must be caused to its surface. For example, when using a board which is 3 cm thick and the fish is of 4 cm, an ideal size of the screw is 6 cm. It is always recommended to use at least 2 screws so that the mount is sufficiently attached to the board.

When the mount is attached to the board, the whole work is finished (Fig. 34).

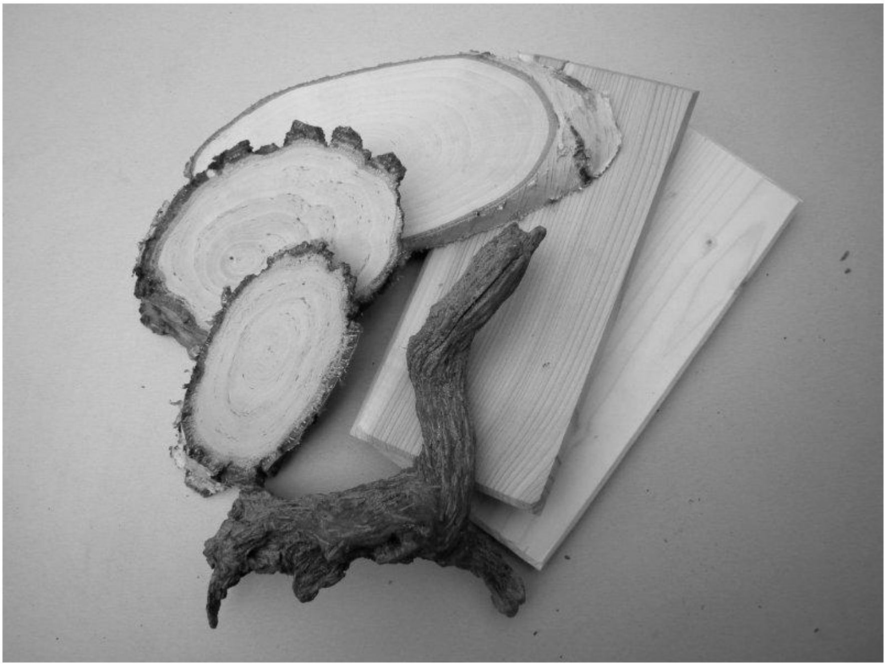


Fig. 33. *For attaching the mount it is possible to use wooden boards or roots of different shapes.*

Fig. 34. *Final appearance of the mounted fish attached according to this methodology.*

2.13. Examples of some successful works

Photographs taken in Salzburg at the Die Hohe Jagd & Fischerei 2012 exhibition show excellent work of the world taxidermists (Fig. 35, 36, 37).

These results can be achieved with the use of the latest methods.

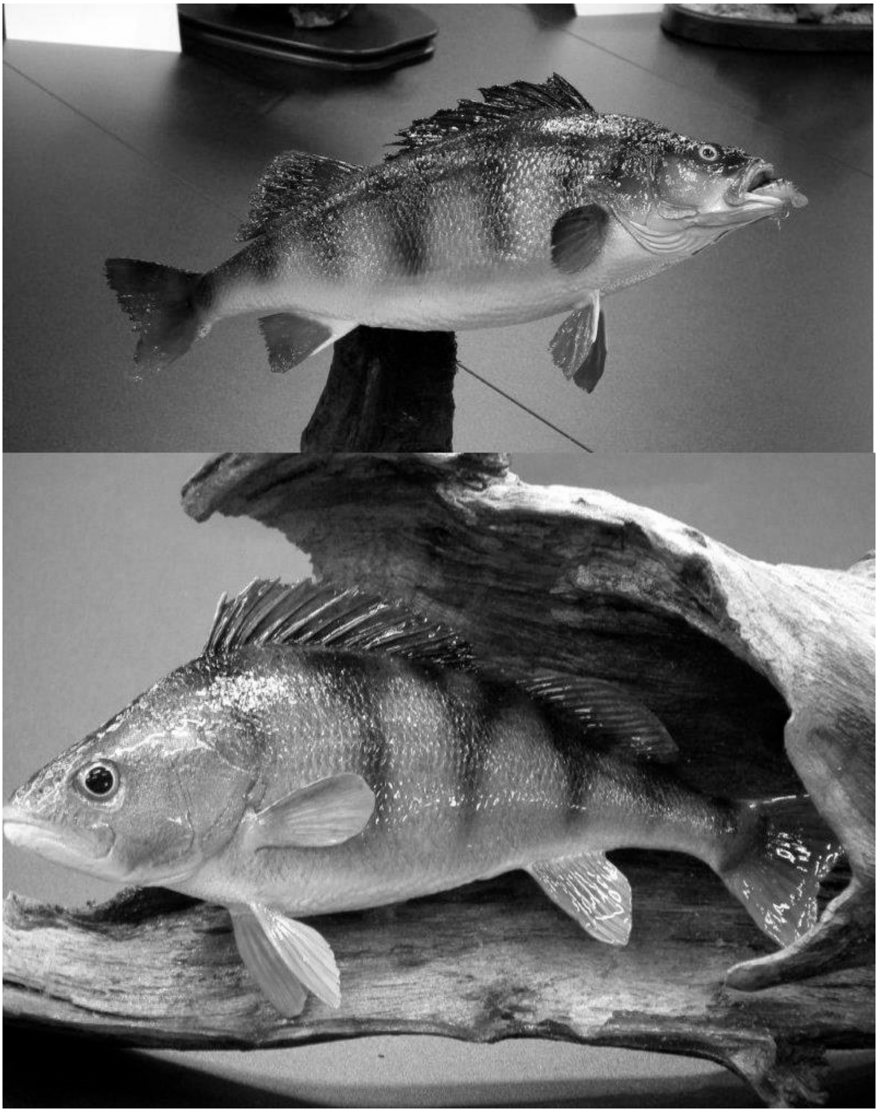


Fig. 35. *Differently coloured perch (**Perca fluviatilis**) from two taxidermists*.

Fig. 36. *Example of a perfectly mounted salmon (**Salmo salar**).*

Fig. 37. *Meticulously performed mount of grayling (**Thymallus thymallus**).*

2.14. Work safety

We are not supposed to eat, drink or smoke during handling the mount which has been treated with formaldehyde. We should also use protective gloves and glasses and work in a well-ventilated room. After the work is finished, it is advisable to properly wash your hands with soap and treat them with a regeneration cream.

Warning:

Formaldehyde

Basic features

Under normal conditions, pure formaldehyde is a colourless gas with a pungent suffocating odour. It has a boiling point of -19.2 °C, a melting point of -118 °C and density of 1,400 $kg.m^{-3}$. Under higher temperatures (> 150 °C) it decomposes into formic acid and carbon monoxide. Its vapours are flammable and explosive. Formaldehyde belongs to volatile organic substances. It is very soluble in water, alcohols and other polar solvents. Because pure gas easily polymerizes, it is usually stored in a form of aqueous solution (25 – 56% formaldehyde). The most frequent concentration on the market is 37 %.

R-phrases

- R 23/24/25 toxic by inhalation, toxic in contact with skin, toxic is swallowed
- R 34 causes burns
- R40 limited evidence of a carcinogenic effect
- R 43 may cause sensitisation by skin contact

S-phrases

- S 1/2 Keep locked up and out of the reach of children
- S 26 In case of contact with eyes, rinse immediately with plenty of water and seek medical advice
- S 36/37/39 Wear suitable protective clothing, protective gloves and eye/face protection
- S 45 In case of an accident or if you feel unwell, seek medical advice immediately (show the label where possible)
- S 51 Use only in well-ventilated areas

http://www.irz/cz/repository/latky/formaldehyd.pdf

3. COMPARISON OF "NOVELTY OF THE PROCEDURES"

The methodology of this way of fish taxidermy and in a form of a monograph has not been published in the Czech Republic so far. However, it is possible to find individual articles in journals relating to this theme (Pelikán, 1991, 1992) or alternatively different methods mentioned in internet contributions and discussions. These usually involve only fragmentary information without practical illustrations.

4. DESCRIPTION OF APPLICATION OF THE CERTIFIED METHODOLOGY

The methodology of whole fish taxidermy is intended primarily for employees of fishery enterprises. It can also be used by employees and members of anglers unions and local organizations.

5. ECONOMIC ASPECTS

Dead fish that are inexploitable for human consumption usually end up as waste in rendering plants. The presented methodology represents a simple, cheap and elegant problem solution in case of death of fish during harvests or accidents. It is possible to prepare from this material very valuable products applicable to the market. It is supposed that when applying this methodology, its users may gain a profit increase amounting up to 200 000 CZK a year.

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Pelikán, P., 1991, 1992. Preparace rybích trofejí. Rybářství [Taxidermy of fish trophies. Fishery]. (7/1991-4/1992).

Advanced Wildlife Design, 2012. Fish Reproduction. In: http://www.advancedtaxidermy.com/index.html. Retrieved on 20th November 2012.

7. LIST OF PUBLICATIONS THAT PRECEDED THE METHODOLOGY

The presented methodology is based on long-time practical knowledge of authors and it has not been published in any form so far.

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CHAPTER 7

FISH HEAD TAXIDERMY

Nebeský, V., Bláha, M., 2014. Fish head taxidermy. Edition of Manuals No. 150. FFPW USB, 29 pp.

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My share on this work was about 90%.

FACULTY OF FISHERIES AND PROTECTION OF WATERS

UNIVERSITY OF SOUTH BOHEMIA IN ČESKÉ BUDĚJOVICE

FISH HEAD TAXIDERMY

V. Nebeský, M. Bláha

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1. AIM OF THE METHODOLOGY

The aim of the methodology is to familiarize readers with an easy and efficient working procedure for the preparation of permanent fish head mounts. The methodology is a follow-up to the already published methodology titled “Whole Fish Taxidermy” (Nebeský and Bláha, 2012) and it will find its use primarily in domestic production fisheries, fishery schools, private fishery districts, museums as well as with the lay public. The methodology of fish head taxidermy will also be appreciated by all sport anglers who are keen on keeping a permanent head mount of their trophy catches.

2. DESCRIPTION OF THE METHODOLOGY

The methodology details the entire production process of permanent fish head mounts intended for decorative or teaching purposes. The methodology provides a time-tested procedure which can be applied to freshwater as well as sea fish species.

2.1. Current techniques

There are not many Czech or foreign literary sources dealing with the fish taxidermy. Several different procedures and instructions are available on the internet, however, these are of a poor quality. Petr Pelikán’s articles titled “Preparation of fish trophies” that were published in the Fishery magazine from the beginning of the 1990s can be considered the most comprehensive fish head taxidermy procedure published so far (Pelikán, 1991, 1992). The latest publication dealing with preparation of dermoplastic fish mounts is the Whole Fish Taxidermy methodology (Nebeský and Bláha, 2012) that was published by the Faculty of Fisheries and Protection of Waters of the University of South Bohemia in České Budějovice.

Taxidermy of fish heads involves an array of possible methods and procedures. The most frequent amateur procedure is represented by a simple desiccation without using any chemicals or alternatively with the use of alcohol or formaldehyde solution (Opatřil, 2010) (Fig. 1). However, fish head mounts obtained in such a way correspond neither to their originals, nor colour, nor shape. Their lifetime is also questionable since imperfectly removed soft tissues often become objects of beetles primarily from the Dermestidae family.

In order to keep the original fish head shape, it is necessary to remove all soft tissues (muscles, ligaments, fat etc.) from it and replace them with a filling which will not change its volume over time. For this purpose, coniferous sawdust combined with various additives (modelling plaster, polystyrene, pearlite etc.) can be used. It is also possible to use lightened materials in a form of moulds, e.g., polyurethane foam. In order to remove water from the tissues, primitive methods involve simple sun exposure. More advanced techniques apply desiccation by means of air blast and higher temperatures. The gentlest method for mount desiccation is so-called vacuum freeze-drying or lyophilisation. Nevertheless, this method requires a special desiccation vessel in which sublimation of frozen water by means of low temperature and pressure occurs. This drying method is used for example by the Austrian Hofinger Tierpräparationen Company (http://www.praeparator.com/int/).

An essential step during preparation of any fish mount is represented by its colouring in or alternatively surface unevenness puttying. Due to applied chemicals and physical processes taking place during the production process a loss of the original fish head colour and skin surface deformations occur. In case of trophies made of fish containing a greater proportion of soft tissues on their heads (catfish, carp, salmonids etc.) it is thus necessary to putty and polish surface unevenness and return the head to its original shape. For subsequent colouring in the mount, there is a great number of techniques on how to achieve the original fish colour. The most common way is the use of brushes and water, oil or acrylic paints (Nebeský and Bláha, 2012). The most ideal result can be achieved through the application of colours by spraying, it is so-called airbrushing, through which it is possible to achieve almost perfect colouring of even the smallest details (Hall and Saxton, 1987). In the USA, preparation of so-called fish replicas has become highly popular. These are casts of fish made in special moulds which are subsequently adjusted to the original's appearance (e.g., the Advanced Taxidermy Company http://www.advancedtaxidermy.com/ or a taxidermist Daniel Hroch, http://www.fishland.cz/).

Fig. 1. *Inappropriately and primitively carried out mount of goliath tigerfish (Hydrocynus goliath)*

2.2. Preparation of the material for the mounting

A high-quality fish head that is to be mounted should ideally come from recently dead or killed fish without any serious damage on the skin surface or fins. It is even possible to use the head from a longer dead fish, but it is necessary to take greater difficulties and potential problems during its treatment into account. The gills colour serves as an indicator whether or not it is possible to use a fish head for the mounting process. If the gills are red or light pink they can be used for the mounting without any problems. In case of fully grey gills, there is already protein slime destruction on the body surface taking place and the skin can be affected by autolytic processes which cause tearing up the skin during removal of the muscles from the head. The most important factor is represented by the temperature which determines the speed of biological as well as chemical processes taking place inside and outside the dead fish body. Therefore, it is required to separate the head from the body immediately after killing the fish or after rigor mortis subsides. Performing the incision at the time of rigor mortis is not recommended as the fish body is usually tensed in the position before arrival of rigor mortis (Sampels et al., 2014). The incision itself separating the fish head from its body must be performed sufficiently far off the opercular archs mainly due to the reason that after the mount is dried, a part of the body must be removed by an inclined incision in order to make it even for the board (Fig. 2). Another reason lies in the utilization of the maximum number of fins, e.g. with fish such as pike-perch or burbot having their abdominal and pectoral fins located close to their heads or a distinctive front dorsal fin with pike-perch or perch.

It is advisable to make a quality photodocumentation of the whole fish including all details for the final colouring-in stage. It is suitable to use a digital camera and take photos during the daytime stray light. Direct sun or artificial lighting could distort the natural colouring to some extent.

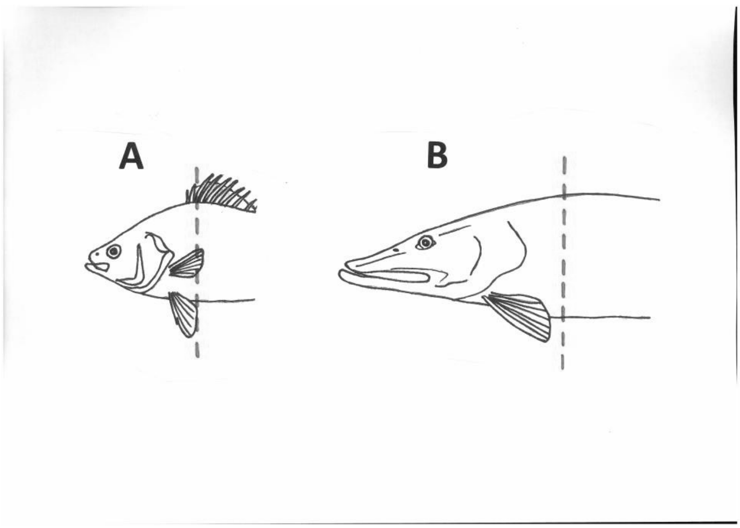

Fig. 2. *Different incisions used for separating the head from the body. A. Perch, B. Pike.*

2.3. Keeping the material before the mounting

If it is impossible to initiate the mounting process immediately, the fish head can be frozen down to -18°C. The freezing process must be paid great attention to. In this case it is primarily required to proceed in such a way that the cooling and subsequent freezing of tissues are performed as quickly as possible. It is also necessary to hermetically wrap up the head into a cover, e.g., a plastic bag or a cling film so that it fits tightly to the skin (Fig. 3). In case of a long-term storage of frozen material, there is a threat of its freezing out (sublimation of water) and occurrence of frozen spots which make the following mounting process more difficult. During the wrapping the fins must be firmly pressed towards the head so that these are not broken when handling the frozen head. It is also essential to wrap up the heads individually as later attempts to separate individual heads from each other could cause damage.

2.4. Unfreezing the material

Unfreezing the fish head is recommended to be carried out as fast as possible in a water bath to prevent development of microorganisms on the fish skin and gills. The best way of unfreezing the fish head is to put it in a tank of a corresponding size containing tepid water of 20 – 25 °C. The fish head must be fully submerged so that the muscles unfreeze evenly. During the primary stage of unfreezing, it is recommended to keep the tightly fitting cover on the skin. On the grounds of better work with a surgical knife, it is recommended to unfreeze the head only 3 – 6 mm deep (Fig. 4) because unfrozen muscles are usually soft and slushy.

Fig. 3. *Frozen head of European catfish (Silurus glanis) tightly wrapped up in a plastic bag*.

Fig. 4. *Unfrozen head of pike (Esox lucius) prepared for the mounting.*

Fig. 5. *Set of tools used for fish head taxidermy.*

2.5. Arrangements for the mounting

Before initiation of the mounting itself, it is necessary to prepare the work surface and instruments (Fig. 5). Close attention must be paid to a worksite which must be well-lit within its entire surface. Due to medical reasons, it is also required to ensure exhaustion of formaldehyde fumes that is used throughout the preparation process as a fixing agent for denaturation of proteins. Work must thus be carried out in a well-ventilated room or a laboratory fume cupboard. It is necessary to use a work mat which must be made of a soft material (e.g., soft foam) and which will adapt to the fish head shape during the mounting process. The mat will also maintain wetness and prevent the surface from becoming dry. The size of the mat must correspond to the size of the fish head that is to be mounted. At this stage, it is advisable to decide on the final appearance of the mount which comprises mainly the fins orientation and the level of jaw and operculum opening.

Fig. 6. *Scrapers for removing subcutaneous fat (left) and jaw openers (right).*

2.6. Removal of the muscles from the fish head

Required aids for this stage are surgical knives, pairs of tweezers, haemostats, preparation needles, scissors, fat scrapers, jaw openers (Fig. 6), a water sprayer, a foam mat, 8% formaldehyde solution, a vessel for the fixation bath and surgical gloves.

The objective of this stage is to remove all muscles and soft tissues from the fish body and head. Possible keeping of muscle remains will manifests itself after the desiccation through deformation or subsidence of the poorly removed tissue. The head is to be carefully put on a moistened mat with the incision heading towards yourself and using the surgical knife, we will cut off the skin from the muscles in the entire circumference.

We will subsequently cut the muscles into larger pieces and by means of the haemostat, we will remove them (Fig. 7). In this way, we will remove the majority of the muscles and soft tissues. This stage is relatively time-demanding; therefore, it is necessary to keep the head surface moistened all the time. With regard to the use of the scalpels, it is necessary to proceed very carefully not to cut through the skin. In order to cut the bones or the backbone, it is suitable to use the pliers. After the stage of the coarse removal of the muscles and most of the bones, the skin is to be cleaned from the remains of the muscles and possible subcutaneous fat is to be removed with a scraper.

Fig. 7. *All soft tissues are gradually removed from the head and the body part.*

The next stage is represented by the removal of the eyes and muscles from the cheek part of the head. The muscles from the cheek parts of the head will be removed through the eye sockets by means of a surgical knife and a longer haemostat or a pair of tweezers (Fig.

8). With regard to a very delicate skin occurring in this place, it is necessary to pay increased attention to the use of sharp instruments (Nebeský and Bláha, 2012). Through the eye sockets, we will open the brain cavity with the pliers and remove the brain with the scraper. Depending on a fish species (e.g., carp, grass carp, silver carp) we will remove the branchial arches and attachments to the cranial skeleton.

Before initiation of the next stage, the head is to be properly washed in clean water and put into a vessel containing the 8% formaldehyde solution. The vessel must correspond to the size of the fish head so that the whole head is submerged in water (Fig. 9). Neither skin nor fins can be bent; otherwise, loosening or falling out of the scales may occur. Fixation time in the formaldehyde solution ranges from 30 to 120 minutes depending on the applied concentration.

Fig. 8. *The haemostat serves to remove the muscles from the cheek part of the head.*

Fig. 9. *Special plastic tanks intended for the formaldehyde bath.*

2.7. Stuffing the mount with the filling mixture

Required aids for this stage: fine sawdust, pearlite, polystyrene, water, modelling plaster, a vessel for mixing the filling mixture, a haemostat, a flat brush, a soft foam mat, a water sprayer.

When the fish head is taken out from the formaldehyde solution, it is necessary to wash it with clean water. If stronger concentration than the recommended formaldehyde solution concentration is applied, it is recommended to leave the head in clean water for 10 to 20 minutes. The filling mixture is to be prepared from fine sawdust (Fig. 10) and a modelling plaster. In order to lighten up the mixture, it is possible to use the pearlite or polystyrene in the ratio up to 1/3 of the mixture volume (Fig. 11). Afterwards, we will add water to the sawdust and pearlite in a suitable vessel in such a way that the mixture remains loose. Adding plaster in the ratio of 5 l of damp mixture : 0.5 kg of plaster follows. The exact proportion cannot be determined with regard to the kind of used ingredients. It is required to obtain a damp mixture that does not relieve water when squeezed.

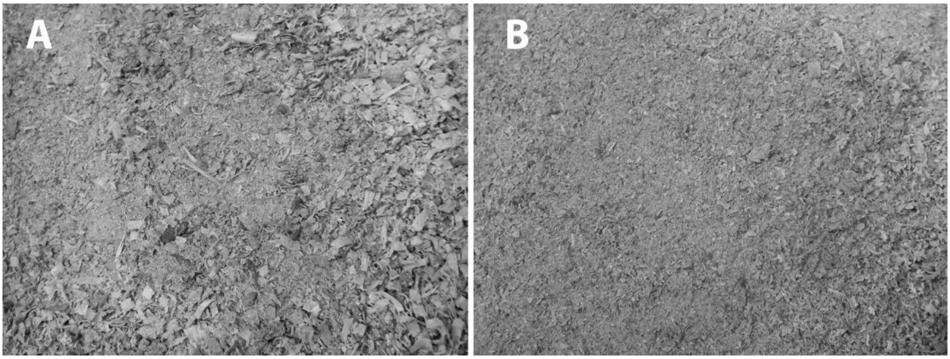

Fig. 10. *Coarse sawdust (A) must be sieved in order to get fine sawdust (B) suitable for the filling mixture with plaster*.

Fig. 11. *Filling mixture made of plaster and sawdust can be lightened up with pearlite or polystyrene*.

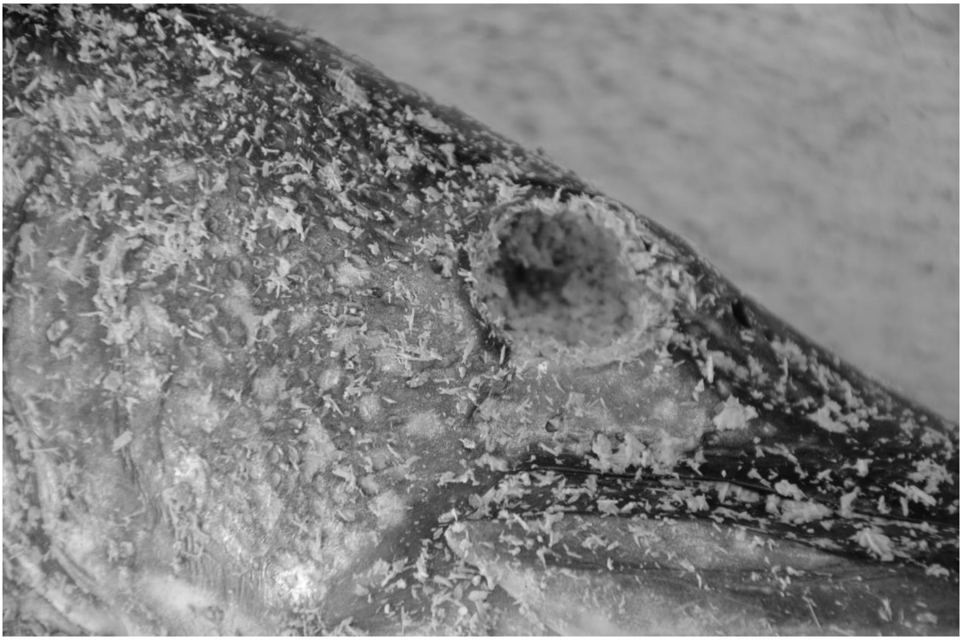

Fig. 12. *Detail of the cheek part of the pike head stuffed with the filling mixture*.

Due to evaporation of formaldehyde (it is classified as a possible carcinogen) from the fish head surface during this stage, it is required to work in a room with air exhaustion. It is also necessary to use surgical gloves that will prevent direct contact of the hands with the fish head surface fixated by formaldehyde (Nebeský and Bláha, 2012).

It is advisable to start filling the cheek part of the head through the eye holes. The mixture is to be tamped down and cheeks are to be adjusted into a preferred shape. In this case it is necessary to pay attention to the fineness of the sawdust used in the mixture. Any coarser particles in the mixture could cause unevenness of the skin which is very delicate in this part of the head (Fig. 12).

After that, the head cavity and the body part behind the head are to be stuffed with the damp filling mixture and gently tamped down. The procedure is to be repeated until the body is wholly stuffed. When stuffing the fish with the mixture, it must be carried out very gently and the new shape of the head and the body part are to be carefully modelled. In case that we improperly tamp down the mixture, there can be sink marks on the fish head after its desiccation. On the other hand, if the fish head is stuffed with too much mixture, it will look unnatural and puffed out.

Solidification of the mixture takes approximately 60 – 180 minutes depending on the kind of used plaster and its proportion to other ingredients.

Fig. 13. *Before the next stage, the mount must be cleaned from the filling mixture remains that cling to the surface.*

Fig. 14. *Cleaned pike head prepared for the desiccation stage.*

When all head parts are wholly stuffed with the mixture and the final shape is modelled, it is required to clean the oral cavity and the head surface with a brush and wash it with water from the filling mixture (Fig. 13).

2.8. Preparation for the mount desiccation

Required aids for this stage are waxed cardboard, paper clips, scissors and surgical gloves.

After the head is perfectly cleaned (Fig. 14) it is to be proceeded to fixing the fish head and fins into a required final shape in which the mount will be desiccated. When preparing for the desiccation, it must be proceeded very carefully because the filling mixture is not entirely solidified and thoughtless treatment could damage the modelled shape of the body or the cheeks.

In order to fixate the fins into a required shape, we will use waxed cardboard which will be double folded and cut out according to the size and shape of the opened fin (Fig. 15). We will insert the stretched fin between the cardboard sheets and attach it with paper clips (Fig. 16). In this way, all fins on the mount head will be fixated.

After fixating the fins, it is necessary to open the jaw and the operculum. In this case, it depends on a taxidermist’s taste. According to our own experience, it is more suitable to fixate the jaw in a more gentle and natural position. A special divider or a wooden peg can serve for fixating the opened jaw. The final activity of this stage is to put the head on a dryer and arranging it into a final shape in which it will be desiccating (Fig. 17).

Fig. 15. *Preparation of the starry sturgeon (Acipenser stellatus) fin to be fixated by means of cardboard sheets.*

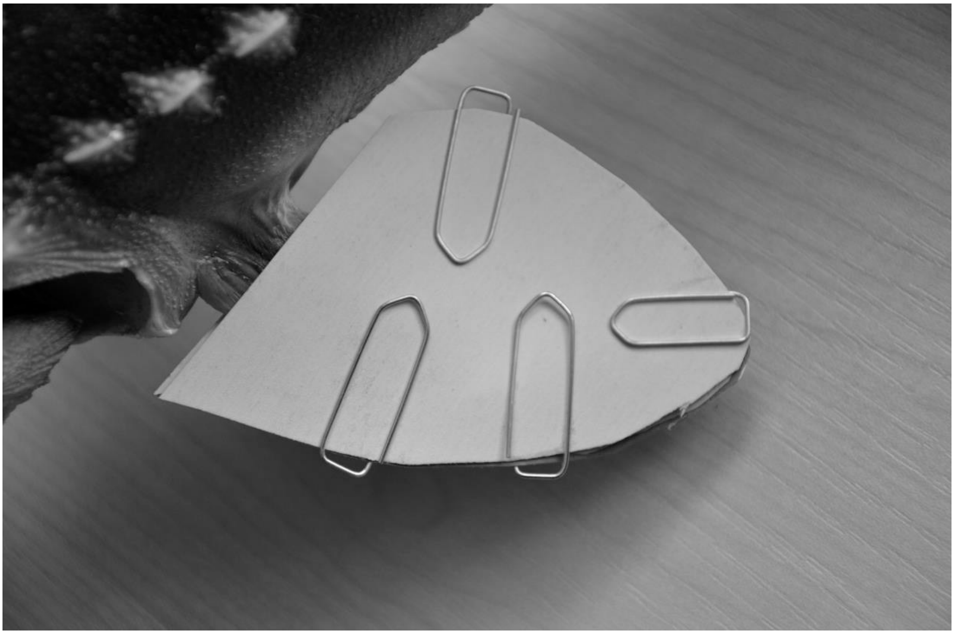

Fig. 16. *Fixation of the sturgeon fin with the use of cardboard sheets and paper clips.*

Fig. 17. *Final position of the pike head mount before its desiccation.*

2.9. Desiccation of the mount

Removal of water from the mount represents a protracted stage which can neither be shortened nor rushed. It is the longest stage of the mounting process. Usual desiccation time depends on the mount size and lasts approximately weeks to months. During the desiccation period, it is advisable to inspect the head every 2 to 3 days.

In order to achieve perfect desiccation conditions, it is necessary to ensure a suitable dry place with sufficient air circulation and temperatures ranging from 20 to 30 °C (Fig. 18) (Nebeský and Bláha, 2012). If these conditions are not observed, mould can start growing in the oral cavity or on the head surface. If mould actually occurs, it is recommended to treat the spot with a pad dipped in the 20% formaldehyde solution and adjust the airflow around the mount.

Fig. 18. *Desiccation of the European catfish (Silurus glanis) head in free space on a metal construction.*

2.10. Cleaning and adjustment of the mount

Required aids for this stage are a surgical knife, an emery paper (grain size no. 80 and 150), a filler, glass eyes and beeswax.

After the mount is perfectly dry, it is time to inspect the mount and retouch possible imperfections which the fish head had had before initiation of the mounting process or which occurred during any stage of the mounting process.

We remove the cardboard sheets and the clips from the fins and clean the entire fish surface with a soft brush (Fig. 19). Protrusions and detached scales should be gently cut off with a surgical knife and polished with emery paper.

Fig. 19. *The mount is to be cleaned from impurities and minor defects are to be adjusted (pike-perch, Sander lucioperca).*

It is necessary to bear in mind that each head mount changes its shape after the desiccation which is caused mainly by the soft tissues under the skin that could not have been removed during the mounting and subsequently replaced with the filling mixture. With regard to fish with a smaller area of these head structures (pike, perch, pike-perch, gurnard etc.), these changes are minimal. On the other head, primarily as far as cyprinids and catfish are concerned, there is a great number of these structures including the subcutaneous fat. Therefore, it is necessary to remodel their original shape. Different fillers and putty are used for these purposes. For the primary surface puttying it is suitable to use a two-component paste with glass fibres (e.g. Rapid). After its solidification, it can be smoothed into a required shape (emery paper with grain size no. 80) or the procedure can be repeated. For the final filling of surface unevenness it is possible to use a fine paste with which it will be possible to retouch even the smallest indentations or wounds. In order to polish the paste, a fine emery paper with the grain size no. 150 can be used.

After that, eye sockets will be cleaned from the redundant filling mixture, unevenness will be treated with a surgical knife, the space will be filled with the beeswax (Fig. 20A) and glass eyes will be sunk in (Fig. 20B). When adjusting the eyes, it is necessary to follow the anatomical structure of the fish eye. The pupil in the fish eye is oval; therefore, an angle of the new eye should correspond to it. Detailed photodocumentation can serve for correct placement and background colouring of the glass eyes. It is also important to sink the eye in the eye socket in the correct depth.

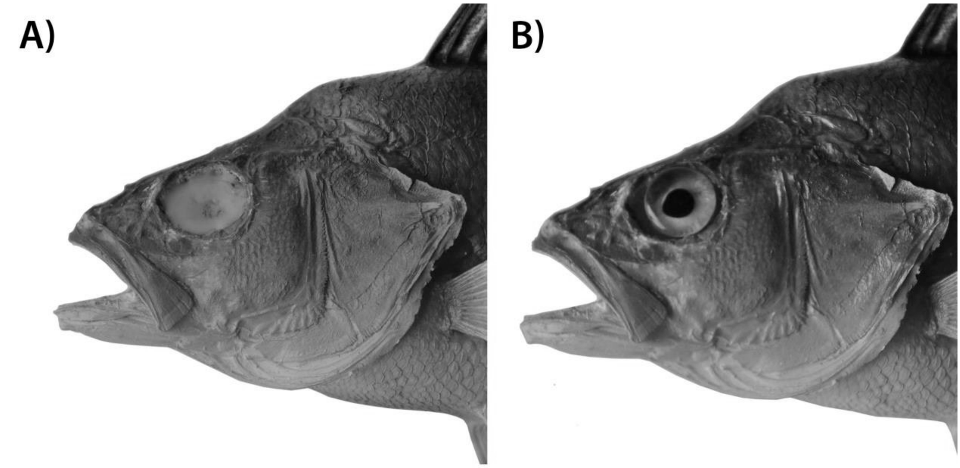

Fig. 20. *Glass eyes are to be sunk in the beeswax (A) in the eye sockets (B).*

Fig. 21. *Crystal fish eyes with an oval pupil.*

Fig. 22. *Original eyes are of more perfect shape and colour.*

Apart from the most common glass eyes with a black oval pupil (Fig. 21) it is also possible to use already coloured eyes (Fig. 22). An advantage of these artificial fish eyes is their faithful reproduction of a concrete shape and colour of a given fish species (http://www.fishland.cz/fishlandan/eshop/7-1-UMELE-RYBI-OCI).

2.11. Colouring in the mount

Required aids for this stage: oil paints, brushes, solvent for oil paints, a wooden palette and clear varnish.

Basically, colouring in the fish heads does not differ from colouring in the whole fish and it represents one of the critical stages of the entire mounting process. Selection of unsuitable paints can easily destroy the whole mount as the colouring requires practice and a certain amount of artistic feelings and skills. Oil paints are the most suitable for colouring in the fish mounts (Fig. 23A) and they are applied by flat or round brushes intended for oil painting (Fig. 23B). The paints can be mixed on a wooden palette or directly on the fish mount.

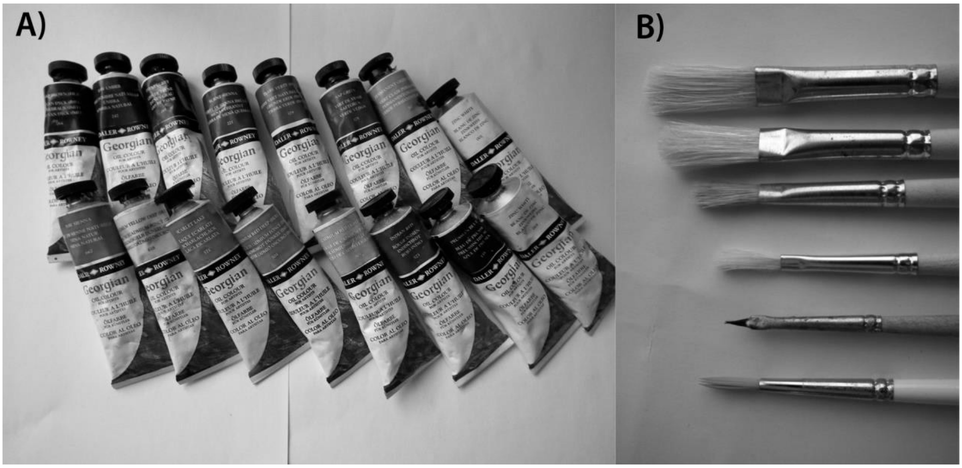

Fig. 23. *Different kinds of brushes (A) and oil paints (B) that are used for colouring in the mounts.*

As a pattern for colouring in the mount, it is recommended to use the photographs of the fish or the head itself which were taken before initiation of the mounting. The photographs serve as a pattern according to which it is possible to capture all the details, colours and their shades. Works connected with the colouring in the mount must be carried out only in daylight.

After finishing the colouring in, it is necessary to put the mount again in a place with sufficient air circulation and temperatures ranging from 20 to 30 °C where the oil paints will sufficiently desiccate. Depending on the type of the used technology and oil, it takes approximately 7 to 14 days. We must always make sure that the paints are perfectly dry. After that, we will thoroughly clean the mount with air blast and cover it with a clear semigloss varnish. With regard to sensitivity of applied paints, it is advisable to use a spray varnish. We should work in a dust-free environment and try to apply an even layer of varnish (Nebeský and Bláha, 2012).

2.12. Attachment of the mount

Required aids for this stage are: a wooden board, a brush, clear varnish and screws.

The perfectly dry, coloured in and varnished head mount is now ready to be installed on the board on which it will be hanging. Suitable material for making the board is wood with a less distinctive drawing structure. The simplest version is attachment onto a wooden board prepared by a straight cut from a tree trunk including the bark – birch, alder, locust, pine etc. (Fig. 24). The board should come from a dried-up wood, it should be 2 – 4 cm thick, filed off at both sides and covered with a clear varnish.

Fig. 24. *Wooden boards are used for attachment of the mount.*

Fig. 25. *Final form of the mounted fish head attached to a wooden board.*

Another option is represented by the use of carved boards from wooden planks. In this case, it is possible to prepare boards of different shapes including decorative reliefs. It again depends on a taxidermist's taste and possibilities or a customer's requirements.

To attach the mount to the wooden board, we will use wooden screws of a corresponding length in such a way that the fish head will be penetrated by the longest part of the screw possible. Depending on the size and weight of the fish head, it is recommended to use at least 3 screws so that the mount is sufficiently attached to the board. After attaching the head to the board, the mount is finished (Fig. 25).

2.13. Example of an unsuitably selected mounting method

Fig. 26 shows an unsuitably selected mounting method where the aesthetical aspect of the mount is highly disputable. With regard to a selected mounting method, the lifetime of the mount is also decreased. During preparation of the mount, no fixation agent was applied and the head was only rid of the muscles and dried. In places where the muscles remained, there are signs of insect activity. Dark places under the skin are caused by mould. A fundamental mistake which destroyed the mount right at the beginning was the separation of the head from the body immediately behind the operculum. Final adjustments of the mount involve only varnishing and no colouring in of the skin. Eye replacements are completely missing. A too small wooden board was chosen which does not cover the pectoral fin and there is thus a threat of it breaking.

Fig. 26 An *unsuitably prepared pike head mount.*

2.14. Work safety

We are not supposed to eat, drink or smoke during handling the mount which has been treated with formaldehyde. We should also use protective gloves and glasses and work in a well-ventilated room. After the work is finished, it is advisable to properly wash your hands with soap and treat them with a regeneration cream.

Warning:

Formaldehyde

Basic features

Under normal conditions, pure formaldehyde is a colourless gas with a pungent suffocating odour. It has a boiling point of -19.2 °C, a melting point of -118 °C and density of 1,400 $kg.m^{-3}$. Under higher temperatures (> 150 °C) it decomposes into formic acid and carbon monoxide. Its vapours are flammable and explosive. Formaldehyde belongs to volatile organic substances. It is very well soluble in water, alcohols and other polar solvents. Because pure gas easily polymerizes, it is usually stored in a form of aqueous solution (25 – 56% formaldehyde). The most frequent concentration on the market is 37 %.

Standard hazard statements (H-phrases):

H351 Suspected of causing cancer

H331 Toxic if inhaled

H311 Toxic in contact with skin

H301 Toxic if swallowed

H314 Causes severe skin burns and eye damage

H317 May cause an allergic skin reaction

H370 Causes damage to organs

Precautionary Statements (P-phrases)

P302+P352 IF ON SKIN: Wash with soap and water

P405 Store locked up

P280 Wear protective gloves/protective clothing/eye protection/face protection

P311 Call a POISON CENTER or doctor/physician

http://www.irz/cz/repository/latky/formaldehyd.pdf

3. COMPARISON OF "NOVELTY OF THE PROCEDURES"

A monograph dealing with this way of fish head taxidermy has not been published in the Czech Republic so far. The most comprehensive published manual for fish head taxidermy can be considered to be the series of articles in the Fishery journal from the beginning of the 1990s (Pelikán, 1991, 1992). Next, it is possible to find different methods mentioned in internet contributions and journals (Gregorka, 2014). This methodology of the fish head taxidermy is a follow-up to the already published methodology titled Whole Fish Taxidermy (Nebeský and Bláha, 2012) which was supplemented with new procedures.

4. DESCRIPTION OF APPLICATION OF THE CERTIFIED METHODOLOGY

The methodology of taxidermy of fish heads is intended primarily for employees of fishery enterprises. It can also be used by employees of museums, fishery schools and members of anglers unions and local organizations.

5. ECONOMIC ASPECTS

Fish heads are usually inexploitable for human consumption and in the majority of cases they end up as waste. On the other hand, for sport anglers, this part of the fish body represents a popular trophy. The presented methodology introduces a simple and practical problem solution in case of death of trophy fish during harvests or accidents. From suitable fish heads it is possible to prepare very interesting products applicable to the market. It is supposed that when applying this methodology, its users may gain a profit increase amounting up to 50 000 CZK a year.

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7. LIST OF PUBLICATIONS THAT PRECEDED THE METHODOLOGY

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“Investing in Sustainable Fisheries”

CHAPTER 8

GENERAL DISCUSSION

Fisheries and aquaculture contribute significantly to the global human food supply. Seafood is a source of high quality protein, vitamins, essential minerals and a source of omega-3 long-chain poly-unsaturated fatty acids. Therefore, fish is an important component in the human diet, but its production is not likely to keep up with demand (Kent, 1997). The increasing population of humans also increases pressure on natural resources, including the food supply. There has been widespread overfishing in coastal and shelf areas, and also on the high seas. Overall marine production has been declining slightly, but there has been compensation in the rapid increase of inland production and aquaculture. According to FAO (2016), the world aquaculture production in marine and inland waters was 73.8 million tonnes in 2014. Worldwide aquaculture production has grown in correlation with the human population. Although the global aquaculture is growing, aquaculture production in the Czech Republic is stagnating, as well as fish consumption (Nebeský et al., 2016). Neighboring landlocked countries such as Slovakia, Austria and Hungary also have similarly low per capita consumption of fish (FAO, 2016). There are several reasons for the low fish consumption in the Czech Republic. The main reason is that common carp (Cyprinus carpio) is the most produced fish in domestic aquaculture but it is harvested and offered to customers only seasonally, i.e. several weeks in a year. In addition, approximately 50% of marketable common carp are exported to Germany (21.8–31.0%) and Slovakia (9.9–13.2%). Another very important factor relative to Czech consumers is one of seasonality related to Christmas, when 80% of annual common carp consumption is eaten in December during the Christmas Eve meal. Many people eat fish just once a year, or not at all (Czech Fish Farmers Association, 2015). The reason for low fish consumption might be that the Czech Republic has no oceanic coast where a tradition of eating fish would have been facilitated. Also, only a small part of the Czech-harvested fish is processed into value-added products. Processing methods from domestic aquaculture is primarily chilled and frozen servings and fillets. Hot smoked fish is the only value-added product available on the Czech market. An increase in consumption of domestically produced fish will require better and diversified processing of common carp and expanding the variety of fish species offered (Nebeský et al., 2016). According to Bronnmann and Asche (2016), the limitation of domestic fish products and seafood in the retail network is generally connected with low consumer demand. As in other parts of the world, consumers in the Czech Republic are increasingly purchasing their food from supermarkets and shopping malls. Though not widely available, fish retail stores are also a growing market presence which may be a suitable approach to provide fish products to customers. In order to maintain the demand for carps and other fish from domestic aquaculture, it will be important to develop high-value-added products that meet the needs of consumers. It is necessary to develop new processing methods to utilize fish meat and expand the range of products for customers. The economic efficiency can be increased by the utilization of separated meat for the production of paté-like products, head, skeleton, viscera and skin for soups, roe for caviar and fillets for marinated fish or ready-to-eat products. Some of these products (Chapter 4 and 5) have been developed by the Industrial Property Office of the Czech Republic under this study and are sold at the Faculty fish shop in České Budějovice and some farmers markets. These high-value-added products compete with imported marine fish food products. Waste and by-products from fisheries and aquaculture are currently increasing because, driven by a growth in seafood products consumption as well as trend toward ready-to-use products. At present, most by-products are used in fish meal and fish oil production. According to Ferraro et al. (2010), waste and by-products can also supply other high value-added compounds for non-food purposes, i.e. collagen and gelatin, taurin, polyunsaturated fatty acids, free amino acids etc. Fish skin can be used to make valuable leather accessories, decorations and teaching materials (Chapter 7 and 8). Processing of these raw materials in the Czech Republic is still not commonly used.

While Czech aquaculture produces nearly 20000 tonnes of fish per year, the Czech market is not self-sufficient and depends largely on imported fishery products. The volume of imported fishery products is twice that coming from domestic aquaculture production (Czech Statistical Office 2017). Therefore, the import and export trends of fishery products in the Czech Republic during 2010–2015 were investigated (Chapter 2). According to findings of Nebeský et al. (2016), in recent years there has been an increasing trend in the import of some commodities in the Czech market. A similar trend is occurring in the entire European Union (EUMOFA, 2016). An obvious interest is evident mainly in the category of high-value aquaculture products such as shrimp and salmon (Nebeský et al., 2016; EUMOFA, 2016). According to Nebeský et al. (2016), Atlantic salmon (*Salmo salar*) (chilled or frozen) became the most imported fish to the Czech Republic surpassing the demand for sutchi catfish (*Pangasianodon hypophthalmus*) (frozen fillet); sutchi cathish sales decreased by 85% during 2010–2015. This decline was caused by changes in customer preference which has also occurred in the European Union (EUMOFA, 2016). The largest increase in fish imports to the Czech Republic has been for a group of crustaceans. Purchasing power increase has been responsible for the sales growth for these high-value products. The value of imports of crustaceans increased by more than 200% during 2010–2015 (EUMOFA, 2016; FAO, 2016). This trend is evident in all developed countries. As mentioned above, around 50% of Czech production of common carp is exported. Common carp remains the largest export commodity from Czech aquaculture. The import of live common carp and other fish to the Czech Republic was only minor.

The quality of fish and seafood products in the Czech retail markets was studied. The aim was to analyze the concentrations of heavy metals and microelements in the most important representative of the current Czech fish production, as well as of the imported seafood products, to assess their safety and hazards for consumers. The most frequently offered and consumed fish and seafood were tested. Many studies have assessed fish quality for marine species (Quetglas et al., 1999; Storelli et al., 2010; Storelli et al., 2012; Pastorelli et al., 2012; Schenone et al., 2013; Olmedo et al., 2013), freshwater cultured species (Svobodová et al., 2002; Orban et al., 2008) and from inland waters with respect to human health risks (Sedláčková et al., 2014). Our study (chapter 3) focused on a general assessment of these products sold to Czech consumers. Fish provide high quality protein, vitamins, essential minerals and lipids, but they also might contain chemical contaminants such as toxic metals (mercury, arsenic, lead and cadmium), polychlorinated biphenyls (PCBs), organochlorine pesticides, aromatic hydrocarbons, dioxin-like polychlorinated biphenyls, polychlorinated dibenzo-p-dioxins, dibenzofurans, polychlorinated diphenyl ethers, polybrominated diphenyl ethers and polychlorinated naphthalenes (Miklavcic et al., 2010). From our analyses heavy metals (mercury, lead, cadmium, arsenic, nickel) and microelements (cooper, zinc) were found in all samples but in very low concentrations, thus representing no risk for consumers. Mercury was the most commonly occurring heavy metal in seafood, as it is around the world (Zhang et al., 2009). A higher total mercury content in marine seafood and in carnivorous fish corresponds with findings Dabeka et al. (2011). The mercury content in common carp was very low which verified safe levels for consumers. Tilapia (*Oreochromis niloticus*) and sutchi catfish had the lowest mercury content in our study. Most of the samples were close or below the limit of quantification (LOQ) for lead. Higher levels of lead and cadmium were recorded in mollusc, which have a natural affinity for these metals (Quetglas et al., 1999; Pastorelli et al., 2012; Olmedo et al., 2013). Nickel and Arsenic content do not represent any risk in this study. In the case of zinc and copper we can say that mollusc can be a good source for human diet and our results are comparable with values obtained by other authors (Celik and Oehlenschlager 2005; Usydus et al., 2009). Although heavy metal content was not significant, monitoring the quality of seafood products should continue so as to assure a safe supply.

Conclusions and future perspectives

It is obvious, that only worldwide sustainable aquaculture based on a considered utilization of natural sources can lead to long-term growth to feed the growing human population. Czech aquaculture is still based mainly on common carp feed on a herbivorous (cereals) diet. Domestic aquaculture production is stabilized; it is up the producers to utilize the fish in a more profitable way by increasing the range of fresh fish meat or extending the range of high-value-added fish products. The aim of Czech producers should be to decrease the export of live fish, which covers 50% of Czech aquaculture production every year. These non-exported and high quality fish should be used for the production of high-value-added goods that will be offered to retail markets and finally to the consumers. For producers as well as for consumers, it is preferable to process high quality domestic fish rather than to importing foreign products from across the world with a diverse, unknown quality. Such changes are already impacting the profitability of producers, processors, retailers in aquaculture and seafood supply chain, and the future actions of regulatory authorities will play a critical role in the industry's future success as it adapts to the new realities.

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ENGLISH SUMMARY

Products from aquaculture: Market, quality and new product development

Fish are one of the main food sources throughout the planet and, in some parts of the world, especially in developing countries they are the only source of animal protein of local residents. Since the beginning of human civilization, fish have been caught in fresh and salt waters. Fishing is still practiced today, but due to the growing human population, the consumption of fish for food and industrial use, and the globalization of trade, most fishing grounds have been decimated or threatened by overfishing. A corrective starting point seems to be the targeted farming or cultivation of aquatic organisms or aquaculture. This term defines the breeding or cultivation of all aquatic animals (fish, crustaceans, molluscs) and plants (algae) for human use. But even aquaculture is not without fault as it brings a variety of negative effects. One of them is, for example, the use of fish meal and oils as a basic ingredient of complex feeds for carnivorous fish species. Fish meal is a globally traded commodity and is made from less valuable fish species caught in the world's seas and oceans. Aquaculture of salmon and similar fish species would not exist without it at the present extent and the breeding of these fish directly affects fishing in salty waters. Freshwater aquaculture is largely based on herbivorous fish in terms of the volume of production. These fish are mainly fed with cereals. Intensive aquaculture, in addition to benefits, also brings problems such as environmental pollution or the use of pharmaceuticals to maintain the health of the organisms and thus the economy of farming. Despite all the problems, aquaculture is probably a better way to ensure the nutrition of the growing population of people on the planet.

Despite the fact that global fish consumption has been constantly increasing and it currently accounts for almost 20 kg of fish per person per year, the situation in the Czech Republic has been changing only slowly. The Czech Republic is known for traditional fish production in pond aquaculture with long historical roots and is currently ranked 6th within the European Union. However, fish consumption is generally one of the lowest in Europe. The annual consumption is only 5.5 kg of fish per person per year, of which fish from domestic aquaculture amount to only 1–1.5 kg. Many people do not even eat fish at all because they reject the specific taste, smell and, above all, the presence of bones in the flesh. This attitude is often passed on to younger generations in families. However, based on our findings from a study on fish and fish products imported into the Czech Republic, new consumer trends in fish and fish products have been emerging. Despite the fact that fish consumption in the Czech Republic has long been low, the interest of consumers has been shifting to more expensive and better quality food such as Atlantic salmon, tuna and crustaceans which lack typical characteristics of products from the Czech aquaculture, i.e. the characteristic taste, aroma and presence of muscle bones. These changes in consumer´s behaviour were recorded on the basis of a study focusing on the import of fishery and aquaculture products into the Czech Republic. A general feature of all these products is also a higher price compared to domestic products. Given the data from statistics of imports, it can be assumed that this trend will continue. At best, there could be an increase in the consumption of fish per capita, which could have a positive impact on consumer´s health. However, the possible scenario is also that imported products will push out products from domestic production because they will not be able to compete with primarily organoleptic characteristics, and then the annual consumption per capita could remain the same. It is therefore highly desirable so that fish from domestic aquaculture get as close as possible to an emerging generation of consumers, using processed products with a high added value, so-called ready-to-eat products. In competition with highly processed and valuable products from imports, our live fish which are offered more or less seasonally cannot compete in the long run. In addition to expanding the portfolio of offered fish species, the solution to this situation could be mainly a higher degree of fish processing as well as the development and introduction of completely new ready-to-eat products from Czech fish into retail chains. One of the goals of this doctoral thesis was the applied results in the form of newly developed products using fish meat, less valuable parts of fish (tailpiece) and wastes from fish processing (skin, head). Due to the nature of these applied results, their registration was done in the form of utility models with the Industrial Property Office of the Czech Republic. One of the newly developed and successfully offered products on the market is carp pâté. It is made of machine-separated carp meat and contains 90% of the meat in the product. In addition to the basic pâté, there are currently other four variants (with pepper, smoked fish, almonds and cranberries). All of these products are naturally gluten-free and have been successfully offered to customers since 2014. Similarly, carp luncheonmeat, which contains 60% of mechanically separated carp meat, has been developed and at the same time uses the tailpiece muscles (30%). This product uses two less valuable raw materials arising from fish processing and at the same time enriches the portfolio of products available to customers. A license agreement with a manufacturing company was concluded for this product in 2016. Within the framework of doctoral studies, certified methods were created for the taxidermy of fish using waste unsuitable for human consumption. From the above, it is clear that there are many possibilities and opportunities how to increase the consumption and use of fish from domestic aquaculture. When introducing new products from fish, which are bred in ponds, the marketing must also be used to promote their indisputable benefits. And this is mainly the fact that it is a healthy and quality domestic raw material from the Czech agriculture. The very high quality and minimal occurrence of foreign substances in products from the Czech aquaculture were confirmed by our study. In the framework of this thesis, the screening of various fishery and aquaculture products, commercially available within the Czech Republic, was carried out with regard to the occurrence of heavy metals. The results of this study showed a very good quality of these products with a low content of heavy metals. Measured values of these elements in products from the Czech aquaculture were well below the allowed limits and their consumption does not pose any health risks. Due to the nature of the data, it is possible to process and publish this study in a popular-scientific form to the general public. The right form of communication and contact with the public will be a key factor in the future in introducing new aquaculture products and increasing fish consumption in the Czech Republic.

CZECH SUMMARY

Produkty z akvakultury: Obchod, kvalita a vývoj nových výrobků

Ryby slouží po celé planetě jako jeden z hlavních zdrojů potravy a v některých částech světa, především v rozvojových zemích, jsou jediným zdrojem živočišných bílkovin tamních obyvatel. Od počátku lidské civilizace jsou ryby loveny ve sladkých i slaných vodách. Lov ryb je provozován i v současnosti, avšak vzhledem ke vzrůstající lidské populaci, spotřebě ryb pro potravinářské i průmyslové využití a globalizaci obchodu je většina lovišť zdecimována nebo ohrožena přelovením. Východiskem se zdá být cílený chov vodních organizmů neboli akvakultura. Tento pojem vymezuje chov či pěstování všech vodních živočichů (ryby, korýši, měkkýši) a rostlin (řasy) pro lidskou potřebu. Ani akvakultura ale není bez vady a přináší nejrůznější negativní efekty. Jedním z nich je např. využívání rybí moučky a olejů jako základní složky komplexních krmiv pro masožravé druhy ryb. Rybí moučka je celosvětově obchodovaná komodita a vyrábí se z méně cenných druhů ryb lovených ve světovým mořích a oceánech. Akvakultura lososa a podobných druhů ryb by bez ní v současné míře neexistovala, a chov těchto ryb tak přímo ovlivňuje lov ryb ve slaných vodách. Sladkovodní akvakultura je z pohledu objemu produkce z velké části založená na rostlinožravých rybách, které jsou krmeny převážně obilovinami. Intenzivní akvakultura kromě benefitů ale přináší i problémy, jako znečištění prostředí či používání farmak pro udržení zdraví chovaných organizmů a tím i ekonomiky chovu. Přes všechny problémy se ale akvakultura jeví jako lepší cesta pro zajištění výživy narůstající populace lidí na planetě.

Přesto, že se celosvětová spotřeba ryb neustále zvyšuje a v současné době činí téměř 20 kg ryb na osobu a rok, situace v České Republice se mění jen pomalu. Česká republika je známá tradiční produkcí ryb v rybniční akvakultuře s dlouhými historickými kořeny a v současné době je na 6. místě v rámci Evropské unie. Nicméně spotřeba ryb je zde obecně jedna z nejnižších v Evropě. Roční spotřeba je pouhých 5,5 kg ryb na osobu a rok, z čehož ryby z domácí akvakultury činí pouze 1–1,5 kg. Mnoho obyvatel dokonce nejí ryby vůbec, neboť odmítají specifickou chuť, vůni a především přítomnost kůstek v mase. Tento postoj je často v rodinách dále předáván na další mladší generace. Na základě našich poznatků ze studie věnované importu ryb a rybích produktů do České republiky se ale u konzumentů projevují nové trendy v konzumaci ryb a rybích produktů. Přesto, že je spotřeba ryb v ČR dlouhodobě nízká, zájem spotřebitelů se přesouvá na dražší a kvalitnější typy potravin. Jsou to právě komodity jako Atlantický losos, tuňák a korýši postrádající typické vlastnosti produktů z české akvakultury, tedy charakteristickou chuť, vůni a přítomnost svalových kůstek. Tyto změny v chování konzumentů byly zaznamenány na základě studie zaměřené na import výrobků z rybolovu a akvakultury do ČR. Obecným rysem všech těchto výrobků je také vyšší cena oproti domácím produktům. Vzhledem k údajům ze statistik dovozů lze předpokládat, že tento trend bude pokračovat i v budoucnu. V lepším případě by mohlo dojít k nárůstu spotřeby ryb na obyvatele, což by z dlouhodobého hlediska mohlo mít pozitivní dopad především na zdraví konzumentů. Avšak je možný i scénář, že importované produkty budou vytlačovat produkty z domácí výroby, protože ty nebudou schopny konkurovat především organoleptickými vlastnostmi, přičemž roční spotřeba na obyvatele zůstane stejná. Je tedy nanejvýše žádoucí, aby se ryby z domácí akvakultury co nejvíce přiblížily nastupující generaci konzumentů, a to pomocí zpracovaných výrobků s vysokou přidanou hodnotou, tzv. „ready-to-eat“ produkty. V kompetici s vysoce zpracovanými a hodnotnými produkty z importů naše živé ryby nabízené víceméně sezonně nemohou z dlouhodobého hlediska obstát. Řešením této situace tak může být kromě rozšíření portfolia nabízených druhů ryb především větší stupeň zpracování ryb, stejně tak jako vývoj a uvedení zcela nových „ready-to-eat“ produktů z českých ryb do obchodních řetězců. Jedním z cílů této doktorské práce byly aplikované výsledky v podobě nově vyvinutých produktů využívajících rybí svalovinu, méně cenné části ryby (ocasní násadce) a odpady vznikající při zpracování ryb (kůže, hlavy). Vzhledem k povaze těchto aplikovaných výsledků bylo přistoupeno k jejich registraci na Úřadu průmyslového vlastnictví ČR formou užitných vzorů. Jedním z nově vyvinutých a úspěšně nabízených produktů na trhu je kapří paštika. Ta je vyráběna ze strojově odděleného kapřího masa, kterého je v produktu 90 %. Kromě základní paštiky v současnosti existují další 4 varianty (s pepřem, s uzeným rybím masem, s mandlemi a s brusinkami). Všechny tyto produkty jsou přirozeně bezlepkové a od roku 2014 jsou úspěšně nabízeny zákazníkům. Podobným způsobem byl vyvinut kapří luncheonmeat, který obsahuje 60 % strojově odděleného kapřího masa a současně využívá svalovinu ocasních násadců (30 %). Tento produkt využívá dvě méně cenné suroviny vznikající při zpracování ryb a zároveň obohacuje portfolio výrobků dostupných zákazníkům. V roce 2016 byla na tento produkt uzavřena licenční smlouva s výrobním podnikem. V rámci doktorského studia vznikly také certifikované metodiky na preparaci ryb využívající odpady nevhodné pro lidskou spotřebu. Z výše popsaného je zřejmé, že je zde mnoho možností a velký prostor, jak zvýšit spotřebu a využití ryb z domácí akvakultury. Při zavádění nových produktů z ryb chovaných v rybnících musí být zapojen také marketing využívajících jejich nesporných benefitů. A to především skutečnost, že se jedná o zdraví prospěšnou a kvalitní tuzemskou surovinu z českého zemědělství. Právě vysoká kvalita a minimální výskyt cizorodých látek v produktech z české akvakultury byl potvrzen naší studií. V rámci této práce byl proveden screening nejrůznějších produktů z rybolovu i akvakultury běžně dostupných v obchodní síti v rámci ČR, a to s ohledem na výskyt těžkých kovů. Výsledky této studie ukázaly velice dobrou kvalitu těchto produktů s nízkým obsahem těžkých kovů. Naměřené hodnoty těchto prvků u produktů z české akvakultury byly hluboko pod povoleným limitem a jejich konzumace nepředstavuje žádná zdravotní rizika. Vzhledem k povaze získaných dat je možné tuto studii zpracovat a zveřejnit v populárně-vědecké formě široké laické veřejnosti. Právě správná forma komunikace a kontakt s veřejností bude v budoucnu klíčovým faktorem pro zavádění nových produktů akvakultury a zvýšení spotřeby ryb v České republice.

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Nebeský, V., Policar, T., 2016. Production, import and consumption of fishery product in the Czech Republic. International Conference: Bonding tradition with innovation – successful strategies in food chain value. TRAFOON, 12–13 September 2016, Olsztyn, Poland.	2016

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