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Proximate and fatty acid composition of 13 important freshwater fish species in central Europe

Zuzana Linhartová [1] · **Jakub Krejsa** [1] · **Tomáš Zajíc** [1] · **Jan Másílko** [1] · **Sabine Sampels** [1] · **Jan Mráz** [1]

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Abstract We aimed to investigate proximate and fatty acid composition of important freshwater fish species in the Czech Republic. Sampled fish include seven species from intensive farming: African catfish, rainbow trout, Wels catfish, Nile tilapia, brook trout, northern whitefish, and pikeperch; eight species from semi-intensive culture systems: common carp, northern pike, pikeperch, grass carp, European perch, tench, silver carp, and catfish; and three species from extensive culture systems: rainbow trout, tench, and common carp. The fat content and fatty acid composition were highly influenced by the culture systems. Simultaneously, we observed a significant dependence of fatty acid composition on the fat content. The content of saturated fatty acids was below 34% in all analyzed fish. Northern pike, pikeperch, and European perch contained with over 50% the highest proportion of polyunsaturated fatty acids. Intensively cultured fish reached the highest content of eicosapentaenoic and docosahexaenoic fatty acid. Nutritional quality was determined by atherogenic and thrombogenic indexes which ranged from 0.27 to 0.63 and 0.20 to 0.61 and by ratios n-3/n-6 (0.54–3.45) and polyunsaturated/saturated fatty acids (0.67–2.01). Results demonstrated that the flesh of all studied species are of high nutritional quality.

Keywords Docosahexaenoic fatty acid · Eicosapentaenoic fatty acid · Fish flesh · Lipid content · Rearing systems

✉ Zuzana Linhartová
linhartova@frov.jcu.cz

[1] Faculty of Fisheries and Protection of Waters, Bohemian Research Center of Aquaculture and Biodiversity of Hydrocenoses, Institute of Aquaculture and Protection of Waters, University of South Bohemia in České Budějovice, Na Sádkách 1780, 370 05 České Budějovice, Czech Republic

Introduction

Global aquaculture is currently one of the most rapidly growing sectors of food production and approximately 50% of the produced fish are for human consumption (FAO 2014). Fish and seafood is considered as a high nutritional quality food with beneficial impact on human health especially due to high content of n-3 highly unsaturated fatty acids (n-3 HUFA) (Adamkova et al. 2011). However, the nutritional composition of farmed fish flesh is variable and dependant on many factors such as rearing conditions and culture system. Especially regarding the fatty acid (FA) composition, one of the major influencing factors is the feed composition, as the FA from the feed will be mirrored in the fish muscle (Morris 2001).

The nutritional importance of fish consumption is associated with a favorable composition of proteins, minerals, vitamins, and essential FA (Lund 2013). In particular polyunsaturated fatty acids (PUFA), especially n-3 long-chain HUFA, the eicosapentaenoic (EPA; 20:5n-3) and docosahexaenoic (DHA; 22:6n-3) FA, found mainly in fish and seafood, have a beneficial effect on human health, especially, the prevention of human coronary disease and weight reduction (Adamkova et al. 2011; Lund 2013). Two subclasses of PUFA are recognized, n-3 and n-6; these are considered "essential" FA because humans lack the Δ12- and Δ15-desaturase enzymes for the synthesis of the shorter chain precursors α-linolenic acid (ALA, 18:3n-3) and linolenic acid (LA, 18:2n-6) and have only a insufficient capacity to desaturate and elongate those to the longer chain PUFA (Adkins and Kelley 2010). Hence, these FA must be supplied in the diet (Calder and Yaqoob 2009). The primary source of n-3 HUFA is algae; it is transferred through the food chain to fish and finally to humans. Marine fish and seafood contain a higher proportion of n-3 HUFA than freshwater fish, which usually have higher proportions of n-6 PUFA, especially LA and arachidonic acid (AA, 20:4n-6) (Ozogul et al. 2007; Huynh and Kitts 2009). The n-3/n-6 ratio varies from 5 to 10 and are higher for marine species (Ozogul et al. 2007). However, freshwater non-carnivorous species can sufficiently biosynthesize the n-3 HUFA from ALA, while marine species have a much lower capability (Tocher 2003). Thus, freshwater fish can be equivalent to marine fish species, as the source of essential FA. Nowadays, western diets tend to be low in n-3 FA, because fish and seafood are not common in the diet and also due to increasing amounts of saturated fatty acids (SFA) and n-6 FA from animal fats, cereals, vegetable oils, and industrial products (Block and Person 2006). Ideally, human nutrition should contain a balanced ratio of n-6 and n-3 FA with WHO/FAO recommendation n-6/n-3 ratio 5:1 or lower (Simopoulos 2002). Currently, western diets have significantly higher ratio ranging between 15:1 and 40:1 which leads to chronic human diseases as for example the metabolic syndrome. Increased intake of n-3 HUFA (EPA and DHA) have shown to reduce the incidence of cardiovascular, coronary artery diseases, cancers, and diabetes (Simopoulos 2002; Adamkova et al. 2011). Studies have shown that the consumption of 1–2 servings of fish (200–400 g)/week and around 18 kg per capita/year outweigh the risks of cardiovascular diseases among adults (Mozaffarrian and Rim 2006; FAO 2014). However, the average consumption is much lower, especially in landlocked countries as the Czech Republic, where the annual fish consumption per capita is app. 5 kg.

Several studies have shown that FA profiles of freshwater fish flesh reflect that of the diet and the rearing conditions (Steffens 1997; Ozogul et al. 2007). It has been reported that fish fat content, type, and amount of FA is influenced by many factors. These factors include fish species, size and age of fish, season, water temperature, geographic location, type of breeding, and nutrition. The fat content and composition varies among different fish species as well as the same species cultured under different conditions (Hara and Radin 1978; Borderias and

Sanchez-Alonso 2011). For example, the lipid and FA profile of commercially important freshwater fish species of Turkey ranged from 0.39 ± 0.06% for pikeperch to 3.21 ± 0.22% for North African catfish (Ozogul et al. 2007). Thus, it is necessary to carry out a study of nutritional values of the major consumed fish in selected localities under various growth conditions. To our knowledge, no such studies have reported the effects of variable culture systems on the FA composition of flesh of major cultured fish in the Czech Republic. Therefore, the objective of this study was to determine proximate and fatty acid composition and nutritional value of the most important freshwater fishes in the Czech market.

Generally, aquaculture is categorized relative to stocking rate and types of feed source: intensive (all feed is supplied, no natural feed), semi-intensive (natural feed is supplemented with additional feed mixtures), and extensive (only natural feed). Representative fish species were selected from all three types of culture systems: intensive, semi-intensive, and extensive. Representatives of intensive farming included seven species: African catfish (*Clarias gariepinus*), rainbow trout (*Oncorhynchus mykiss*), Wels catfish (*Silurus glanis*), Nile tilapia (*Oreochromis niloticus*), brook trout (*Salvelinus fontinalis*), northern whitefish (*Coregonus peled*), and pikeperch (*Sander lucioperca*); eight species cultured semi-intensively: common carp (*Cyprinus carpio*), northern pike (*Esox lucius*), pikeperch, grass carp (*Ctenopharyngodon idella*), European perch (*Perca fluviatilis*), tench (*Tinca tinca*), silver carp (*Hypophthalmichthys molitrix*), and Wels catfish; as well as three species from extensive farming: rainbow trout, tench, and common carp. The choice of the studied species was based on the increment of domestic demand and also in the world market so as to provide nutritional information to the consumer, who are currently uninformed and mistrustful of different freshwater fish species.

Materials and methods

Fish and sample collection

Market size fish, from intensive, semi-intensive, and extensive culture systems, were obtained from rivers, ponds, and aquaculture facilities from different localities (Table 1) in the Czech Republic during the year 2014. After capture, fish were separated according to the size and only marketable-size individuals were retained. Selected fish were killed by a blow to the head; weighted (Table 1) and immediately transported on ice (0 °C) to the processing facilities of the Institute of Aquaculture and Protection of Waters (IAPW), Faculty of Fisheries and Protection of Waters (FFPW), University of South Bohemia (USB), Ceske Budejovice, Czech Republic. Fish were filleted but the skin was retained and only the left fillet was used for the further analyses. Scales were removed, fillets were homogenized in blender Ultra-turrax (Janke and Kunkel, IKA Werke, Germany), and the mince was stored in tight PVC packages at − 80 °C until further analyses.

Lipid extraction

Lipids were extracted following the method of Hara and Radin (1978) with some modifications described by Mraz and Pickova (2009). A 1-g sample was homogenized and lipids were extracted in hexan-isopropanol (HIP, 3:2), subsequently mixed with 6.67% Na_2SO_4 and centrifuged at ×5000 rpm for 5 min at 18 °C. Lipid phase (upper one) was transferred to glass

Table 1 List of 13 sampled freshwater fish species from different culture systems in the Czech Republic with major information about type of farming, origin, food habits, average weight (g), and number (n) of examined fish

Fish	Latin name	Type of farming	Origin	Food habits	Average weight (g)	Number tested (n)
African catfish	*Clarias gariepinus*	Intensively	FFPW	Carnivorous	1870	6
rainbow trout	*Oncorhynchus mykiss*	Intensively	FFPW	Carnivorous	470	7
Wels catfish	*Silurus glanis*	Intensively	Prague	Carnivorous	2700	11
Nile tilapia	*Oreochromis niloticus*	Intensively	Trebon	Omnivorous	650	6
Brook trout	*Salvelinus fontinalis*	Intensively	Klatovy	Carnivorous	300	6
Northern white-fish	*Coregonus peled*	Intensively	FFPW	Omnivorous	100	6
Pikeperch	*Sander lucioperca*	Intensively	Prague	Carnivorous	560	6
European perch	*Perca fluviatilis*	Semi-intensively	Chlumec nad Cidlinou	Carnivorous	150	9
Wels catfish	*Silurus glanis*	Semi-intensively	Chlumec nad Cidlinou	Carnivorous	4000	12
Common carp	*Cyprinus carpio*	Semi-intensively	Blatna	Omnivorous	2500	14
Northern pike	*Esox lucius*	Semi-intensively	Blatna	Carnivorous	1000	4
Tench	*Tinca tinca*	Semi-intensively	Trebon	Omnivorous	680	4
Grass carp	*Ctenopharyngodon idella*	Semi-intensively	Trebon	Herbivorous	2400	4
Silver carp	*Hypophthalmichthys molitrix*	Semi-intensively	Trebon	Omnivorous	1600	8
Pikeperch	*Sander lucioperca*	Semi-intensively	Pisek	Carnivorous	1500	6
Rainbow trout	*Oncorhynchus mykiss*	Extensively	Loucna	Carnivorous	300	5
Tench	*Tinca tinca*	Extensively	Loucna	Omnivorous	210	5
Common carp	*Cyprinus carpio*	Extensively	Blatna	Omnivorous	2500	6

tube and evaporated under nitrogen atmosphere. Total lipid content was determined gravimetrically and stored at − 80 °C for methylation.

Fatty acid composition (gas chromatography)

A 2-mg sample of extracted lipids was taken for analysis. Fatty acid methyl esters (FAME) were prepared by methylation with NAOH in dry methanol (0.01 M), boron-trifluoride methanolcomplex (BF_3), NaCl, and hexan. The FAME were analyzed by gas chromatograph (GC) Trace Ultra (Thermo Scientific, USA) equipped with flame ionization detector (FID) and capillary column BPX 70 (AGE, Austin, TX, USA) with film of length × diameter × thickness: 50 m × 0.22 mm × 0.25 μm. FA were identified by comparison with a standard mixture GLC-68D (Nu-Check Prep, Elysian, USA) and other individual standards. The absolute amount of individual FA was calculated by using an internal standard (21:0) (Nu-check Prep, Elysian, USA).

Proximate composition and nutritional data

Proximate and nutritional composition of fish samples were determined by dry matter, proteins, lipids, ash content (g/100 g), and energy value (kJ/100 g) according to standard procedures. To determine dry matter, 15–20 g of pre-dried (at 105 °C) sea sand was mixed with 5 g of homogenized flesh in pre-dried porcelain dishes and dried at 105 °C to the constant weight. Ash was analyzed by incineration of 5 g homogenized samples at 550 °C in a muffle furnace for 4 h. The dried/incinerated samples were cooled in desiccator to avoid the risk of increased humidity and weighed. Protein content was calculated from the amount of total nitrogen using 6.25 as a conversion factor. Total nitrogen was analyzed by UDK 132 automatic distillation unit in certified laboratory at Faculty of Agriculture, SBU, České Budějovice, Czech Republic. Energy value was calculated assuming conversion factors (formula) from the amount of protein, lipids, and carbohydrates (formula) (NRC 1993).

Formulas for carbohydrates content and energy value:

$$\text{Carbohydrates } (\%) = 100\text{–}(\text{moisture} + \text{lipids} + \text{proteins} + \text{ash})$$

$$\text{Energy value } (\text{kJ}/100\text{ g}) = \text{proteins (g)} \times 23.6\text{ kJ} + \text{lipids (g)} \times 39.5\text{ kJ} + \text{carbohydrates (g)} \times 17.2\text{ kJ}$$

Health lipid indices

The nutritional indices of atherogenicity (AI) and thrombogenicity (TI) were calculated from the of FA data according to Ulbricht and Southgate (1991). The AI indicates the risk of formation of diseases as atherosclerosis (fat deposition in the walls of arteries) and the TI defines the possibility of blood clots formation. AI is the ratio between the sum of main SFA (myristic 14:0 and palmitic 16:0) and the sum of monounsaturated FA (MUFA) and PUFA, while TI is the ratio between pro-thrombogenic (myristic 14:0, palmitic16:0 and stearic18:0) and anti-thrombogenic (MUFA, n-6 PUFA and n-3 PUFA) FA (Ulbricht and Southgate 1991; Garaffo et al. 2011). These indices were calculated according to the formulas:

$$\text{AI} = (4 \times 14:0 + 16:0)/[\Sigma\ \text{MUFA} + \Sigma\ \text{PUFA}]$$

$$\text{TI} = [14:0 + 16:0 + 18:0]/[(0.5 \times \text{MUFA}) + (0.5 \times n\text{–}6\ \text{PUFA}) + (3 \times n\text{–}3\ \text{PUFA}) + (n\text{–}3/\text{n–}6)]$$

Moreover, ratios between polyunsaturated/saturated (P/S) and n-3/n–6 PUFA were determined according to Department of Health and Social Security, Diet and cardiovascular disease (1984).

Statistical analyses

All data were calculated as means ± standard deviations (SD). Total lipid content (%) and absolute amount of EPA + DHA (mg/100 g flesh) were evaluated using analysis of variance

(ANOVA) with subsequent post hoc comparisons using Tukey's honest significant difference (HSD) test. Probability values of $P < 0.05$ were considered as significant. All statistical analyses were performed using STATISTICA software (Version 12, StatSoft, Inc., 2013) for MS Windows.

Results and discussion

General

The nutritional quality, proximate, and FA composition of 13 important freshwater fish from the Czech Republic were documented (Table 1). Fish species were selected from three different culture systems: extensive ($n = 3$), semi-intensive ($n = 8$), and intensive ($n = 7$). Fish selection was based on anticipated differences in fat content and FA composition relative to the feeding protocol in each system. Thus, the second aim of this study was to compare proximate and FA composition of same species reared in different systems and the fat content based on variable growth only fish of marketable size were analyzed (Table 1).

Total lipid content

Fish can be divided into four categories according to their fat content: lean (< 2.5%), low fat (2.5–5%), medium fat (5–10%), and high fat (> 10%). The lipid content in the chosen 13 freshwater species was strongly affected by culture system, but mostly by semi- and intensive farming.

The common carp is the most important semi-intensively cultured species in the Czech Republic which has a large variability of fat content during the year (Mraz et al. 2012; Zajic et al. 2013). In this study, the lipid content (7.62%) was higher than that reported by de Castro et al. (2007) or Ozogul et al. (2007) who classified carp among lean fish (< 2.5%). These values correspond rather to the fat content only of white muscle (Zajic et al. 2013) which is an irrelevant information for human consumption as usually whole fillets are consumed. Moreover, the fat content was also investigated in carp harvested from ponds where they had only natural feed (extensively cultured); extensively reared carp had lower fat content (4.09%), indicating that carp reared in semi-intensive conditions with cereal feed had a significant impact on the increase of fat (Zajic et al. 2013; Másílko et al. 2015). As expected, among semi-intensively cultured fish, common carp, silver carp, and grass carp had the highest lipid content, there were no significant differences and they were considered to be medium fat fish (5–10%). Silver carp is generally considered a high fatty fish. Fat content is strongly affected by the weight and can reach to 20% in larger size fish (Razavi et al. 2014). In this study, fat content was found to be up to 6.87%, which is significantly lower than the level reported by Razavi et al. (2014). This difference is most probably due to the smaller sizes of the analyzed fish which however are frequently sold in the market and hence shows a more realistic nutritional composition to the consumers. On the other hand, carnivorous species such as European perch, northern pike, and pikeperch contained significantly lower levels at < 1% fat. Compared to the present work (0.77%), similar data were documented by Orban et al. (2007) with 0.76% of fat in European perch. Identical results were reported for northern pike by Żmijewski et al. (2006), but higher fat levels of 2–2.4% were found by Kucska et al. (2006)

in larger fish. Surprisingly, Wels catfish, commonly considered by the consumers as a “rather fatty” fish, had a very low fat content with the value of only 2.97%. These results coincide with studies of Füllner and Wirth (1996), Hallier et al. (2007); Cirkovic et al. (2012) and Stancheva et al. (2014). Comparing the fat content and size of the analyzed fish in the various studies, we can assume that fat content increases with increasing body weight of fish.

The fat content of intensively reared fish is relatively high due to the greater proportion of fat in the feed. This statement was confirmed by salmonids in the present study, where brook trout showed 10.3% of fat content. However, significantly different values were found in Wels catfish and Nile tilapia. In this group, Wels catfish showed the lowest fat content of 4.13%; these data suggest that this fish should be considered as low fatty fish as Ljubojevic et al. (2013). Fat proportion of Nile tilapia was 4.42% and of African catfish 7.42% resembling the results of Ozogul et al. (2007) and Rosa et al. (2007) with a range of 3–5%. This slightly higher amount is caused by different quality and quantity of feeding. For this reason, we can include intensively farmed African catfish and Nile tilapia from the Czech Republic in the group of fish with low or medium fat content.

Fish from the extensively cultured group are generally characterized by low fat content. The fat content of these fish (carp, tench, and rainbow trout) were compared with same species reared in different culture systems (carp and tench from semi-intensive and rainbow trout from intensive farming); except for tench, they all showed significantly different values between the culture systems (Fig. 1a). Extensively reared rainbow trout showed a fat content of 2.41% similar to the value reported by Popelka et al. (2014). On the other hand, intensively cultured rainbow trout contained 9.78% of fat which reinforces the statement of Kose and Yildiz (2013) that the feed mixtures utilized in intensive culture systems significantly increases the fat content of farmed fish compared to fish from extensive systems. This difference was also documented for carp, reaching average values of fat content of semi-intensively farmed fish of 7.62 ± 2.92% vs. 4.09 ± 1.22% in the extensive ones. In opposite, in tench, no significant differences were observed (Fig. 1a), indicating that the final fat content is sometimes more depending on the fish species than the rearing conditions.

Moreover, the fat content of semi-intensively cultured Wels catfish and pikeperch (2.97 and 0.79%) was compared with intensively reared fish (4.13 and 1.11%) which is presented in Fig. 1b. Low levels of fat content were found in both analyzed species and both culture systems.

Fatty acid composition

Twenty-one FA (%) were identified in all species; their relative proportions (%) are summarized in Table 2. The absolute amount of EPA + DHA in mg/100 g flesh is illustrated in Fig. 2: (a) intensively cultured fish, (b) semi-intensively reared fish, and (c) extensively cultured fish. The highest amount was identified in intensively cultured brook trout (1442 mg/100 g) and the lowest in semi-intensively reared grass carp (127 mg/100 g). As with the lipid content, the FA composition is strongly affected by the type of culture system and nutrition.

The semi-intensively farmed fish, European perch, pikeperch, and northern pike were characterized by a high percentage of EPA + DHA (Table 3), but the absolute amounts (mg/100 g) were considerably lower in comparison with other species of this group (Fig. 2b) due to the low fat content. Similar proportions of EPA + DHA for European perch, the highest value in this group (33.46%), was found by Orban et al. (2007). However, in the case of northern pike, the values for EPA and DHA (6.88 and 21.85% in present study) varied considerably, from 20 to 30% and 27.96% reported by Żmijewski et al. (2006). The highest absolute

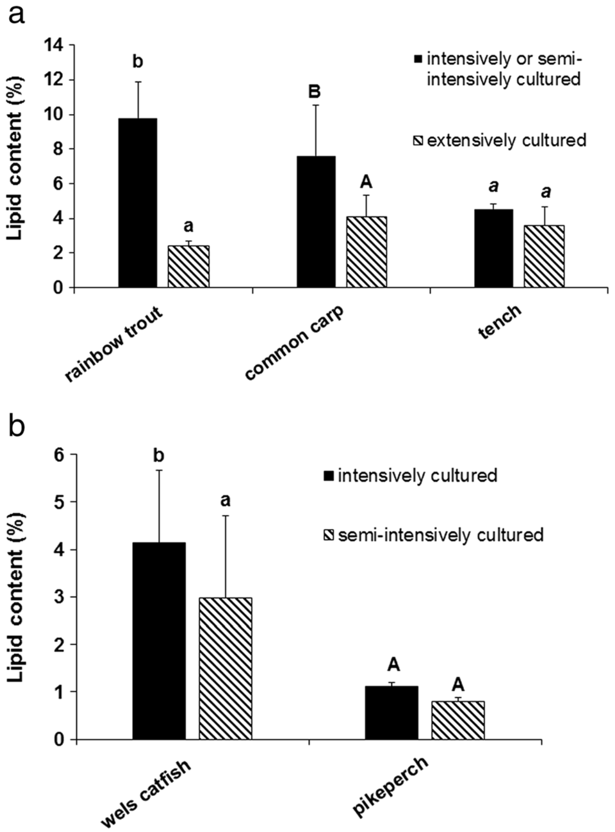

Fig. 1 Comparison of lipid content (%) (mean ± standard deviation) of **a** intensively cultured rainbow trout and semi intensively reared common carp and tench with fish from extensive culture systems and **b** intensively cultured Wels catfish and pikeperch with fish from semi-intensive farms. Bars with the same letter are not significantly different (Tukey's test, $P < 0.05$)

amounts of EPA and DHA were detected in silver carp (471 mg/100 g) and tench (319 mg/100 g) corresponding to their higher fat content. The proportion of EPA and DHA (2.96 and 1.81%) in carp differed significantly from the values reported by Ozogul et al. (2007) (5.86% EPA and 8.21% DHA). This could be explained by the different fat content: 7.62% in this study compared to 0.88% found by Ozogul et al. (2007) which had harvested the fish in different seasons as well as by differences in feed. Carp is in general classified as a medium fat fish with lipid content 5–10% and has shown a variable lipid composition depending on many factors, e.g., amount and composition of natural food or feeding mixture. Mraz and Pickova (2009) showed that it was possible to increase contents of EPA and DHA by feeding a diet containing rapeseed cake. Furthermore, it has also been proven that the fatty acid composition of this carp is beneficial to human health. Adamkova et al. (2011) reported the significant improvement of plasma lipid parameters in Czech patients after major cardiac revascularization surgery when they ate carp (200 g twice a week for 4 weeks).

The intensively farmed fish, pikeperch, brook trout, and northern whitefish showed statistically identical percentages of EPA and DHA in the range of 15.63–17.83%. This fact could correspond to a very similar composition of feed for these fish species in intensive culture

Table 2 Fatty acid composition (% of identified) of seven freshwater fish species from intensive culture systems

	African catfish	Rainbow trout	Wels catfish	Nile tilapia	Brook trout	Northern whitefish	Pikeperch
14:0	2.48 ± 1.06	2.25 ± 0.38	3.76 ± 0.95	4.53 ± 0.36	5.05 ± 0.29	4.74 ± 0.35	1.18 ± 0.13
14:1	ND	ND	ND	ND	ND	ND	ND
16:0	20.95 ± 1.45	14.84 ± 1.23	14.10 ± 1.38	23.55 ± 2.01	14.89 ± 0.65	15.29 ± 0.66	16.30 ± 0.94
16:1	3.81 ± 1.12	3.08 ± 0.35	4.47 ± 0.84	6.15 ± 1.02	7.28 ± 0.29	7.32 ± 0.29	2.09 ± 0.19
18:0	5.89 ± 0.91	3.82 ± 0.42	3.57 ± 0.97	5.64 ± 0.29	2.67 ± 0.18	2.28 ± 0.15	3.35 ± 0.76
18:1n-9	32.36 ± 10.01	29.64 ± 0.98	24.41 ± 4.85	31.06 ± 3.17	20.23 ± 0.63	26.59 ± 1.64	33.89 ± 1.84
18:1n-7	3.27 ± 0.86	2.52 ± 0.16	ND	3.80 ± 0.38	3.47 ± 0.22	4.39 ± 2.07	2.91 ± 0.09
18:2n-6	13.17 ± 0.87	25.58 ± 1.14	10.08 ± 2.46	11.93 ± 0.37	9.99 ± 0.33	9.30 ± 0.40	15.99 ± 1.28
18:3n-3	2.75 ± 0.56	3.65 ± 0.22	2.08 ± 1.37	1.68 ± 0.39	5.00 ± 0.74	2.52 ± 0.11	3.72 ± 0.28
20:0	0.27 ± 0.04	0.20 ± 0.07	0.22 ± 0.06	0.21 ± 0.08	ND	0.19 ± 0.02	0.18 ± 0.06
20:1n-9	2.93 ± 1.09	1.45 ± 0.60	7.02 ± 2.38	1.96 ± 0.43	2.03 ± 0.09	6.05 ± 0.82	1.22 ± 0.35
20:2n-6	0.50 ± 0.04	0.87 ± 0.30	0.54 ± 0.32	0.53 ± 0.08	4.81 ± 0.27	0.42 ± 0.02	0.45 ± 0.02
20:4n-6	0.70 ± 0.31	0.61 ± 0.22	0.31 ± 0.20	1.29 ± 0.21	1.22 ± 0.11	0.56 ± 0.03	1.12 ± 0.21
20:3n-3	0.16 ± 0.07	0.14 ± 0.07	6.73 ± 4.86	0.13 ± 0.10	3.41 ± 0.30	0.19 ± 0.04	0.13 ± 0.05
22:0	0.09 ± 0.04	0.10 ± 0.05	0.60 ± 0.30	ND	0.28 ± 0.01	ND	ND
22:1	0.41 ± 0.13	0.40 ± 0.21	ND	0.24 ± 0.13	ND	0.53 ± 0.09	0.40 ± 0.05
20:5n-3	2.85 ± 2.03	2.45 ± 0.31	4.36 ± 1.01	0.86 ± 0.36	6.13 ± 0.25	6.50 ± 0.35	3.05 ± 0.52
22:5n-6	ND	ND	0.21 ± 0.14	ND	ND	0.15 ± 0.30	ND
24:1	0.19 ± 0.09	ND	ND	ND	ND	0.33 ± 0.04	0.21 ± 0.08
22:5n-3	0.94 ± 0.53	0.91 ± 0.33	2.55 ± 0.41	1.93 ± 0.31	1.93 ± 0.14	1.32 ± 0.59	1.23 ± 0.10
22:6n-3	6.21 ± 4.20	7.54 ± 0.44	8.76 ± 2.28	4.25 ± 0.51	10.49 ± 0.59	11.33 ± 0.97	12.58 ± 1.08
ΣSFA	29.69 ± 1.58	21.01 ± 1.89	22.25 ± 1.61	33.96 ± 2.29	22.90 ± 1.08	22.49 ± 0.92	21.04 ± 1.36
ΣMUFA	43.01 ± 7.01	37.22 ± 1.07	37.36 ± 5.23	43.43 ± 1.86	33.02 ± 0.73	45.22 ± 1.19	40.70 ± 2.07
ΣPUFA	27.29 ± 5.96	41.77 ± 1.61	34.61 ± 2.62	22.61 ± 1.06	42.08 ± 1.09	32.39 ± 0.58	38.26 ± 1.46
Σn-3 PUFA	12.92 ± 6.24	14.71 ± 0.72	24.48 ± 5.17	8.86 ± 0.99	26.96 ± 1.06	21.86 ± 0.63	20.70 ± 1.25
Σn-6 PUFA	14.37 ± 0.72	27.06 ± 1.16	11.13 ± 2.71	13.75 ± 0.31	16.02 ± 0.08	10.43 ± 0.43	17.55 ± 1.22
Σn-3 HUFA	10.17 ± 6.76	11.05 ± 0.77	22.39 ± 6.49	7.18 ± 0.75	21.95 ± 0.70	19.34 ± 0.70	16.99 ± 1.45
EPA + DHA	9.07 ± 6.23	10.00 ± 0.51	13.12 ± 2.36	5.11 ± 0.68	16.62 ± 0.77	17.83 ± 0.92	15.63 ± 1.38

DHA docosahexaenoic fatty acid, *EPA* eicosapentaenoic fatty acid, *HUFA* highly unsaturated fatty acids, *MUFA* monounsaturated fatty acids, *ND* not defined, *PUFA* polyunsaturated fatty acids, *SFA* saturated fatty acids

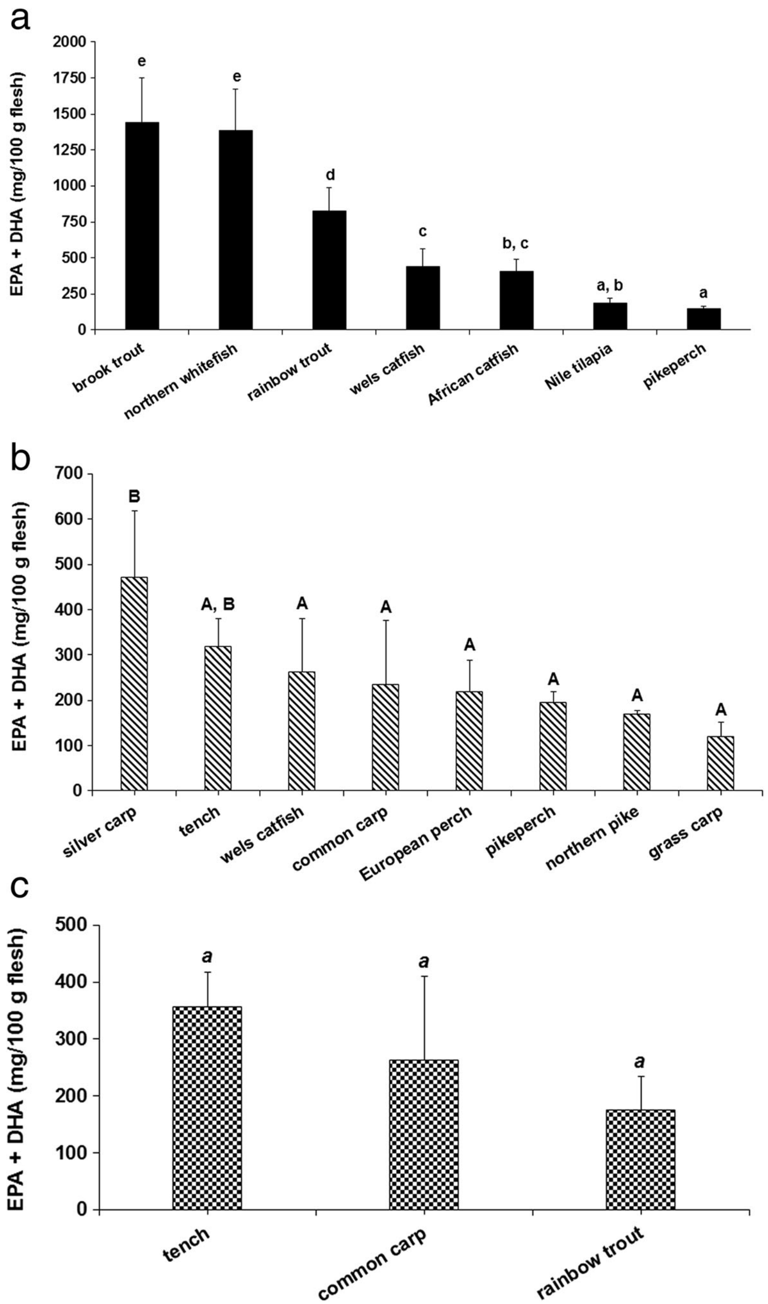

Fig. 2 The absolute amount (mg/100 g flesh) of eicosapentaenoic (EPA) and docosahexaenoic (DHA) fatty acids in the fillets of **a** seven intensively cultured freshwater fish species, **b** eight semi-intensively reared freshwater fish species, and **c** three extensively cultured freshwater fish species. Data are shown as mean ± standard deviation and bars having the same character are not significantly different (Tukey's test, $P < 0.05$)

systems, which are based on fishmeal and fish oil, rich in EPA and DHA (+ other PUFA). Limiting effect is only the fat content of the fish flesh which varies within species despite

Table 3 Eight freshwater fish species from semi-intensive fish farms

	European perch	Wels catfish	Common carp	Northern pike	Tench	Grass carp	Silver carp	Pikeperch
14:0	0.96 ± 0.19	1.75 ± 0.32	1.62 ± 0.36	0.83 ± 0.31	2.40 ± 0.07	1.58 ± 0.25	2.86 ± 1.00	2.13 ± 0.15
14:1	0.09 ± 0.06	0.36 ± 0.15	0.26 ± 0.31	0.06 ± 0.03	0.15 ± 0.11	ND	0.24 ± 0.17	0.28 ± 0.06
16:0	24.52 ± 1.07	17.18 ± 1.85	19.64 ± 1.30	21.06 ± 0.66	21.20 ± 0.33	22.13 ± 1.94	22.91 ± 1.25	20.47 ± 0.85
16:1	3.63 ± 0.63	9.51 ± 3.38	6.44 ± 4.06	3.95 ± 1.64	12.88 ± 0.39	9.09 ± 1.07	10.31 ± 0.51	5.94 ± 0.48
18:0	5.92 ± 0.33	4.18 ± 0.90	6.27 ± 0.73	4.68 ± 0.26	3.09 ± 0.09	4.53 ± 0.25	4.47 ± 0.32	4.21 ± 0.08
18:1n-9	9.66 ± 0.81	28.15 ± 6.90	41.14 ± 9.79	14.10 ± 2.85	23.38 ± 0.38	31.65 ± 3.34	28.84 ± 1.56	11.08 ± 0.66
18:1n-7	3.85 ± 0.31	ND	3.65 ± 0.74	3.84 ± 0.90	6.17 ± 0.04	2.76 ± 0.33	4.09 ± 0.26	4.92 ± 0.10
18:2n-6	3.23 ± 0.31	5.43 ± 1.83	7.51 ± 1.30	6.27 ± 0.41	8.29 ± 0.11	10.15 ± 1.53	3.74 ± 0.40	4.13 ± 0.38
18:3n-3	1.45 ± 0.62	4.34 ± 1.34	3.81 ± 1.64	2.89 ± 0.44	7.26 ± 0.16	10.72 ± 1.76	8.33 ± 0.83	5.38 ± 0.45
20:0	0.15 ± 0.05	0.21 ± 0.08	0.09 ± 0.09	0.11 ± 0.19	0.30 ± 0.02	0.16 ± 0.02	0.24 ± 0.03	0.28 ± 0.03
20:1n-9	0.37 ± 0.15	2.06 ± 0.69	1.16 ± 0.75	0.33 ± 0.09	0.60 ± 0.08	0.93 ± 0.07	1.11 ± 0.11	0.42 ± 0.03
20:2n-6	0.27 ± 1.00	0.55 ± 0.19	0.29 ± 0.71	0.66 ± 0.02	0.87 ± 0.02	0.49 ± 0.11	0.54 ± 0.63	0.30 ± 0.02
20:4n-6	9.35 ± 1.07	2.40 ± 2.42	1.33 ± 1.22	9.40 ± 1.80	3.57 ± 0.01	1.27 ± 0.19	2.16 ± 0.44	6.82 ± 0.59
20:3n-3	0.27 ± 0.14	0.31 ± 0.37	0.27 ± 0.22	0.23 ± 0.04	0.49 ± 0.01	0.71 ± 0.10	0.67 ± 0.08	0.90 ± 0.06
22:0	ND	0.91 ± 0.58	ND	ND	0.10 ± 0.04	0.16 ± 0.07	0.06 ± 0.05	0.09 ± 0.10
22:1	ND	ND	ND	ND	ND	0.36 ± 0.22	ND	ND
20:5n-3	5.49 ± 1.00	3.50 ± 1.15	2.95 ± 2.77	6.88 ± 0.56	5.30 ± 0.03	0.78 ± 0.16	4.17 ± 1.67	6.35 ± 0.37
22:5 n-6	ND	ND	ND	ND	ND	ND	ND	ND
24:1	ND	ND	ND	ND	ND	ND	ND	ND
22:5n-3	2.55 ± 0.23	2.17 ± 0.45	0.73 ± 0.61	2.76 ± 0.32	0.97 ± 0.06	0.73 ± 0.14	1.21 ± 0.13	3.51 ± 0.42
22:6n-3	27.97 ± 2.97	9.76 ± 4.84	1.81 ± 1.62	21.85 ± 3.93	2.96 ± 0.18	1.80 ± 0.39	4.01 ± 1.01	22.69 ± 1.08
ΣSFA	31.59 ± 1.07	24.23 ± 1.88	27.62 ± 1.40	26.71 ± 0.46	27.13 ± 0.25	28.56 ± 2.03	30.55 ± 0.72	22.10 ± 1.02
ΣMUFA	17.83 ± 1.12	41.61 ± 7.85	52.71 ± 7.75	22.35 ± 5.35	43.15 ± 0.20	44.78 ± 2.62	44.61 ± 1.74	22.77 ± 1.15
ΣPUFA	50.57 ± 1.23	28.86 ± 9.83	18.75 ± 7.63	50.94 ± 5.15	29.72 ± 0.19	26.65 ± 2.82	24.85 ± 2.21	50.05 ± 1.71
Σn-3 PUFA	37.73 ± 1.70	20.10 ± 6.56	9.58 ± 6.24	34.61 ± 3.95	16.69 ± 0.18	14.74 ± 2.13	18.40 ± 1.93	38.80 ± 1.48
Σn-6 PUFA	12.84 ± 0.95	8.77 ± 3.77	9.18 ± 1.85	16.33 ± 1.91	12.73 ± 0.12	11.91 ± 1.75	6.45 ± 0.96	11.26 ± 0.25
Σn-3 HUFA	36.25 ± 1.98	15.75 ± 6.33	5.78 ± 5.04	31.72 ± 4.04	9.72 ± 0.27	4.02 ± 0.68	10.06 ± 2.51	33.45 ± 1.86
EPA + DHA	33.46 ± 2.14	13.26 ± 5.72	4.77 ± 4.37	28.73 ± 3.78	8.26 ± 0.20	2.58 ± 0.47	8.19 ± 2.50	29.04 ± 1.42

DHA docosahexaenoic fatty acid, *EPA* eicosapentaenoic fatty acid, *HUFA* highly unsaturated fatty acids, *MUFA* monounsaturated fatty acids, *ND* not defined, *PUFA* polyunsaturated fatty acids, *SFA* saturated fatty acids similar feed. For example brook trout reached the value of 1443 mg/100 g EPA and DHA, while African catfish contained only 405 mg/100 g flesh. In rainbow trout, EPA and DHA represented 2.75 and 7.25% of the total lipid content, which is in the range of the values of 2.1–9.5% EPA and 5–13% DHA found for this species by Popelka et al. (2014).

Lower contents of both EPA and DHA were found in extensively cultured rainbow trout, carp and tench (Table 4) in comparison with semi-intensively reared species which is clearly an effect of nutrition. The lowest absolute amount of EPA and DHA (176 mg/100 g) was found in rainbow trout in comparison with other extensively cultured species, indicating that their natural diet was low in these FA.

As expected, the content of individual FA is species variable. The only exception was found in SFA with < 30% representation in all analyzed fish except for silver carp (30.55%), European perch (31.59%), and Nile tilapia (33.96%).

In the case of semi-intensively farmed fish, omnivorous and herbivorous fish had higher percent of MUFA than carnivorous, most probably because they were fed with high energetic feedings and stored the excess of energy in fat in the form of MUFA (especially oleic acid; 18:1 n–9). The content of MUFA in common carp in the present study was 52.71% which is significantly higher than found earlier 32% by Jabeen and Chaudhry (2011) or even 21.05% by Stancheva et al. (2014). This clearly corresponds to the supplemented feedings composed of

Table 4 Three freshwater fish species from extensive farming in the Czech Republic. Data are shown as mean ± standard deviation (SD)

	Rainbow trout	Tench	Common carp
14:0	2.02 ± 0.62	2.43 ± 0.46	1.70 ± 0.27
14:1	ND	0.21 ± 0.12	0.17 ± 0.09
16:0	18.96 ± 3.65	21.24 ± 0.43	21.33 ± 1.82
16:1	4.69 ± 1.13	14.24 ± 1.91	0.83 ± 0.39
18:0	5.00 ± 1.38	2.40 ± 0.49	1.44 ± 2.77
18:1n-9	32.64 ± 13.47	18.87 ± 0.49	39.24 ± 3.99
18:1n-7	3.85 ± 0.99	4.89 ± 1.56	4.37 ± 0.52
18:2n-6	15.81 ± 3.21	8.61 ± 0.78	12.61 ± 2.72
18:3n-3	1.36 ± 0.59	9.96 ± 1.94	5.45 ± 2.06
20:0	0.20 ± 0.05	0.28 ± 0.04	0.09 ± 0.05
20:1n-9	1.70 ± 0.82	0.50 ± 0.10	0.11 ± 0.02
20:2n-6	0.95 ± 0.24	0.49 ± 0.04	0.38 ± 0.13
20:4n-6	3.28 ± 1.94	2.04 ± 0.19	0.33 ± 0.11
20:3n-3	0.17 ± 0.05	0.54 ± 0.11	0.17 ± 0.27
22:0	ND	ND	ND
22:1	0.15 ± 0.07	0.03 ± 0.02	0.14 ± 0.04
20:5n-3	1.62 ± 1.00	6.74 ± 0.39	3.55 ± 1.11
22:5 n-6	ND	ND	ND
24:1	ND	ND	ND
22:5n-3	0.56 ± 0.18	1.23 ± 0.54	1.49 ± 0.54
22:6n-3	6.85 ± 1.51	5.23 ± 1.18	3.64 ± 1.53
ΣSFA	26.24 ± 5.18	26.42 ± 1.16	24.57 ± 1.19
ΣMUFA	43.17 ± 11.03	38.24 ± 2.87	44.86 ± 3.48
ΣPUFA	30.59 ± 6.13	34.84 ± 3.69	27.61 ± 3.99
Σn-3 PUFA	10.55 ± 3.02	23.7 ± 3.02	14.30 ± 3.95
Σn-6 PUFA	20.04 ± 4.95	11.14 ± 0.84	13.32 ± 2.60
Σn-3 HUFA	9.19 ± 2.48	13.74 ± 1.59	8.85 ± 2.94
EPA + DHA	8.46 ± 2.29	11.96 ± 1.55	7.18 ± 2.42

DHA docosahexaenoic fatty acid, *EPA* eicosapentaenoic fatty acid; *HUFA* highly unsaturated fatty acids, *MUFA* monounsaturated fatty acids, *ND* not defined, *PUFA* polyunsaturated fatty acids, *SFA* saturated fatty acids cereals (Mraz et al. 2012; Zajic et al. 2013). In this study, the content of MUFA in extensively cultured carp resulted in 44.86%. The same decreased content of MUFA in fish from extensive systems compared to semi-intensive was also observed in tench in the present work. Carnivorous fish, such as European perch (17.83%) contained lower amounts of MUFA compared to the proportions reported by Orban et al. (2007) (21.91%). However, Wels catfish, a carnivorous species, had a much higher proportion of MUFA (41.61%), in line with studies by Cirkovic et al. (2012) and Stancheva et al. (2014) who found also higher proportions of MUFA (35.61 and 50.02% respectively). This increased MUFA composition was probably caused by the consumption of larger fish with high MUFA content in comparison with smaller carnivorous fish. Similarly, high proportions of MUFA was also detected in extensively cultured fish. The highest value was found in carp containing 44.86% MUFA (Table 4).

In intensively farmed fish, northern whitefish, Nile tilapia, and African catfish had MUFA proportions above 43%. Northern whitefish showed the highest value of MUFA (45.22%). This difference was most probably affected by the feed composition and the intensity in the applied rearing system.

High PUFA % was found in carnivorous fish: northern pike (50.94 ± 5.15%) and pikeperch (50.05 ± 1.71%). The lowest PUFA content, among the semi-intensively cultured fish was found in common carp (18.75 ± 7.63%).

The highest composition of *n*–3 HUFA was detected in European perch (36.25%), pikeperch (33.45%), and northern pike (31.72%). Other fish species had values below 30% and grass carp showed the lowest one (4.02%). This is mainly influenced by the nutrition as well as fatness of analyzed fish.

Proximate composition

Due to the increasing demand on information about nutritional composition of food, proximate and nutritional composition of fish were analyzed by determination of dry matter, proteins, lipids, and ash content (g/100 g) and energy value (kJ/100 g) (Table 5). The proportions of carbohydrates and salt were not determined because of their minimal natural occurrence in freshwater fish flesh. Protein composition of fish can vary according to the fish species, size, season, gender, but usually the content is up to 20% (Erkan and Ozden 2007). In all species, the protein content ranged from 15 to 20% corresponding to the literature findings (Gjedrem et al. 2012; Zotos and Vouzanidou 2012). An almost linear correlation between lipid and dry matter content was found in the studied fish species. Fattier fish, such as northern whitefish, showed a higher proportion of dry matter (31.69 ± 0.69%) compared to the lean fish as for example European perch, showed significantly lower dry matter contents (20.37 ± 0.61%).

Health and nutritional value evaluation

The nutritional quality of lipid profiles observed in all fish were evaluated by the following indices: AI, TI, P/S, and n-3/n-6 (Table 6). The AI and TI indicate the value of a fat source for human health with high values representing a higher risk of the development of cardiovascular diseases. These indicators are described in detail by Ulbricht and Southgate (1991), who identified these values for pork (AI 0.60 and TI 1.37), beef (AI 0.72 and TI 1.27), and chicken (AI 0.50 and TI 0.95). In this study, results of these indicators were well balanced in most species and did not reach the value 0.5 for AI and TI. Higher indices were found only in Nile tilapia, where AI reached 0.63 ± 0.06 and TI 0.61 ± 0.08. These data suggest that fish flesh is a

Table 5 Proximate composition of 13 freshwater fish species from the Czech Republic. Data are shown as mean ± standard deviation (SD)

Species	Culture systems	Dry matter (g/100 g)	Proteins (g/100 g)	Lipids (g/100 g)	Ash (g/100 g)	Energy value (kJ/100 g)
African catfish	Intensive	30.68 ± 0.52	17.50 ± 1.18	9.71 ± 1.93	1.13 ± 0.08	836.71 ± 25.45
Rainbow trout	Intensive	30.61 ± 0.17	16.25 ± 0.13	11.41 ± 0.33	2.13 ± 0.25	848.15 ± 15.16
Wels catfish	Intensive	25.41 ± 0.15	16.02 ± 0.17	3.31 ± 1.08	2.22 ± 0.05	575.22 ± 23.52
Nile tilapia	Intensive	26.21 ± 1.65	17.98 ± 0.53	4.83 ± 0.85	1.56 ± 0.10	646.75 ± 49.08
Brook trout	Intensive	33.02 ± 1.95	18.54 ± 0.16	9.66 ± 1.81	2.84 ± 0.29	853.19 ± 65.32
Northern whitefish	Intensive	31.69 ± 0.69	16.71 ± 0.33	9.82 ± 2.31	1.73 ± 0.25	841.20 ± 65.34
Pikeperch	Intensive	22.28 ± 0.91	18.47 ± 0.84	1.11 ± 0.05	1.73 ± 0.26	496.47 ± 21.69
European perch	Semi-intensive	20.37 ± 0.61	16.55 ± 0.27	0.80 ± 0.05	1.72 ± 0.46	444.57 ± 6.97
Wels catfish	Semi-intensive	20.77 ± 1.00	16.82 ± 1.03	0.84 ± 0.06	1.61 ± 0.45	455.96 ± 30.14
Common carp	Semi-intensive	24.25 ± 1.81	17.56 ± 0.58	6.48 ± 1.30	1.81 ± 0.36	626.96 ± 62.72
Northern pike	Semi-intensive	22.46 ± 0.25	18.62 ± 0.23	0.75 ± 0.13	2.23 ± 0.05	483.92 ± 7.39
Tench	Semi-intensive	24.10 ± 0.99	17.32 ± 0.50	4.22 ± 0.18	2.23 ± 0.53	581.06 ± 14.34
Grass carp	Semi-intensive	25.95 ± 0.95	17.66 ± 0.41	5.07 ± 0.86	1.97 ± 0.15	638.63 ± 30.38
Silver carp	Semi-intensive	26.48 ± 1.27	17.62 ± 0.11	5.78 ± 1.47	1.60 ± 0.22	669.72 ± 58.76
Pikeperch	Semi-intensive	21.21 ± 0.93	17.34 ± 0.95	0.79 ± 0.08	1.35 ± 0.11	470.19 ± 21.13
Rainbow trout	Extensive	26.06 ± 0.92	19.73 ± 0.84	2.63 ± 0.04	1.75 ± 0.51	602.92 ± 29.22
Tench	Extensive	24.16 ± 1.66	17.23 ± 1.63	3.65 ± 1.35	2.12 ± 0.71	570.77 ± 34.62
Common carp	Extensive	23.09 ± 1.22	17.56 ± 0.58	3.02 ± 0.73	1.57 ± 0.23	549.80 ± 24.98

more suitable product for a healthy nutrition for humans than the previously mentioned pork, beef, and chicken meat. The P/S ratios indicate the possibility to induce cholesterol increase in the blood and a P/S value below 0.45 has been considered to be undesirable for the human diet (Department of Health and Social Security, Diet and cardiovascular disease 1984).

Table 6 Nutritional indexes and weekly serving (g), corresponding to 1750 mg eicosapentaenoic (EPA) and docosahexaenoic (DHA) fatty acids, of 13 studied freshwater fish species from different culture systems in the Czech Republic. Data are mean ± standard deviation (SD)

Species	Culture systems	AI	TI	P/S	n-3/n-6	Servings (g)
African catfish	Intensive	0.44 ± 0.09	0.45 ± 0.08	0.92 ± 0.17	0.91 ± 0.47	432
Rainbow trout	Intensive	0.29 ± 0.05	0.27 ± 0.03	2.01 ± 0.25	0.54 ± 0.03	212
Wels catfish	Intensive	0.40 ± 0.07	0.22 ± 0.04	1.56 ± 2.61	2.42 ± 1.09	397
Nile tilapia	Intensive	0.63 ± 0.06	0.61 ± 0.08	0.67 ± 0.06	0.64 ± 0.07	943
Brook trout	Intensive	0.46 ± 0.03	0.21 ± 0.02	1.88 ± 1.01	1.68 ± 0.06	121
Northern whitefish	Intensive	0.44 ± 0.03	0.23 ± 0.01	1.44 ± 0.63	2.10 ± 0.13	126
Pikeperch	Intensive	0.27 ± 0.02	0.23 ± 0.01	1.83 ± 0.13	1.19 ± 0.13	1185
European perch	Semi-intensive	0.41 ± 0.02	0.24 ± 0.02	1.60 ± 1.15	2.96 ± 0.28	884
Wels catfish	Semi-intensive	0.34 ± 0.03	0.27 ± 0.04	1.20 ± 5.22	2.50 ± 0.69	665
Common carp	Semi-intensive	0.37 ± 0.04	0.48 ± 0.10	0.68 ± 5.37	1.00 ± 0.46	747
Northern pike	Semi-intensive	0.33 ± 0.01	0.21 ± 0.02	1.91 ± 1.29	2.14 ± 0.26	1036
Tench	Semi-intensive	0.42 ± 0.01	0.33 ± 0.00	1.10 ± 0.76	1.33 ± 0.02	549
Grass carp	Semi-intensive	0.40 ± 0.05	0.39 ± 0.06	0.94 ± 0.14	1.26 ± 0.27	1419
Silver carp	Semi-intensive	0.49 ± 0.04	0.36 ± 0.03	0.81 ± 3.03	2.91 ± 0.49	371
Pikeperch	Semi-intensive	0.40 ± 0.02	0.20 ± 0.01	1.84 ± 1.68	3.45 ± 0.07	897
Rainbow trout	Extensive	0.37 ± 0.10	0.41 ± 0.10	1.17 ± 1.18	0.54 ± 0.18	993
Tench	Extensive	0.42 ± 0.04	0.27 ± 0.04	1.32 ± 3.18	2.12 ± 0.20	491
Common carp	Extensive	0.39 ± 0.03	0.34 ± 0.06	1.12 ± 3.35	1.13 ± 0.45	666

AI atherogenic index, *DHA* docosahexaenoic fatty acid, EPA eicosapentaenoic fatty acid, *TI* thrombogenic index, *P/S* ratio between polyunsaturated/saturated fatty acids, *n-3/n-6* ratio between Σ of the omega 3/Σ of the omega 6 polyunsaturated fatty acids

In the present study, the P/S ratios ranged from 0.67 ± 0.06 in Nile tilapia to 2.01 ± 0.25 in rainbow trout (intensively cultured). Also, *n*–6/n–3 ratio below 4.0 has been shown to prevent the risk of cardiovascular diseases (Department of Health and Social Security, Diet and cardiovascular disease 1984) and ranged from 0.54 ± 0.03 in rainbow trout (from intensive breeding) to 3.45 ± 0.07 in pikeperch (semi-intensively cultured). All these nutritional indices confirm that fish are beneficial for human consumption.

Regular consumption of fish (1–2 servings/week), especially of species with higher EPA and DHA content, reduced risk of coronary disease by 36% and total mortality by 17%. The minimum recommended daily intake of combined EPA and DHA of 250 mg/day lowered these risks by at least 25% (Mozaffarrian and Rim 2006; EFSA 2010). This can be converted to a weekly intake (= 250 × 7), resulting in a recommended weekly intake of 1750 mg EPA and DHA. The amount of the individual fishes to fulfill this recommended weekly intake is listed in Table 6. This means that for adequate intake of EPA + DHA is sufficient to consume from 121 to 1419 g of fish per week (Table 6). This corresponds to 0.8 serving of brook trout or northern white fish but on the other hand almost 9.5 servings of grass carp, by considering 150 g as an average portion. By comparing different types of fish, the intake is related the total fat content and hence the intake of lean fish has to be higher than oily fish. Thus, we can alter the world famous statement "to include 'fatty' fish in the diet at least two times per week. As we showed that n-3 content strongly depends on species fat content and feed."

Conclusion

This study represents a step towards the characterization of proximate and FA composition of 13 economically important freshwater fish species from intensive, semi-intensive, and extensive culture systems of the Czech aquaculture. The results of this work confirmed that the fat content and its FA composition are highly influenced by the type of culture system especially by the diet. The omnivorous common carp (7.62 ± 2.92%) and herbivorous silver carp (6.87 ± 1.37%) had the highest fat content from semi-intensively cultured fish. On the other hand, the carnivorous fish showed low fat contents usually around 1%. The fish from extensive farms were more balanced in their lipid content (around 3% for all species). Simultaneously, we observed a significant dependence of FA composition on the fat content. The lean carnivorous fish contained lower amounts of EPA + DHA in comparison with the fatty northern whitefish containing 17.83% (intensively cultured). The content of SFA was below 34% in all analyzed fish. The highest content of MUFA was found in common carp (52.71 ± 7.75%), and the lowest in European perch (17.83 ± 1.12%). Northern pike, pikeperch, and European perch contained with over 50% the highest proportion of PUFA. Consequently, all analyzed fish, except for Nile tilapia, had low values of both AI and TI (< 0.5) which shows a great benefit for human health if these fish are included in the human diet. Summarizing, the results of present study provide important nutritional information about the selected fish.

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Compliance with ethical standards

Conflict of interest The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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