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FATTY ACID COMPOSITION OF FISHES FROM INLAND WATERS

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Abstract

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The paper presents a comparative analysis of proximate and fatty acid composition of seven fish species from the Danube River including asp (*Aspius aspius*), common bream (*Abramis brama*), common barbel (*Barbus barbus*), common carp (*Cyprinus carpio*), sterlet (*Acipenser ruthenus*) and northern pike (*Esox lucius*).

Eight samples of each species of freshwater fish were caught from the Danube. The amount of protein ranged from 16.69 g/100 g (common carp) to 18.61 g/100 g (barbel). Fat content in the fillets of pike, asp, bream, sterlet, common carp and barbel was 1.61; 2.78; 3.24; 5.39; 7.13 and 7.78 g/100 g, respectively. The total cholesterol content was the highest in the sterlet fillets (73.59 mg/100 g) and the lowest in the asp (36.26 mg/100 g). The total amount of saturated fatty acids was the highest in pike (39.9%) and the lowest in bream (27.27%). The sum of polyunsaturated fatty acid was however the highest in pike (28.15%) and the lowest percentage of PUFA was in bream (17.07%) and the lowest n-3/n-6 ratio was in common carp (0.44).

The chemical composition and quantity of n-3 fatty acids varied largely by the fish species. The meat of warm water fishes from the Danube River represents a valuable source of healthy nutrition for the consumers.

Key words: chemical composition; the Danube, fatty acids; free catching, freshwater fish; total cholesterol
Abbreviations: SFA – saturated fatty acids; MUFA – monounsaturated fatty acids; PUFA – polyunsaturated fatty acids; USFA – unsaturated fatty acids; EPA – eicosapentaenoic acid; DHA – docosahexaenoic acid; ALA – α-linolenic acid, BW – body weight

Introduction

Fish meat possesses high nutritional quality and is therefore a particularly recommended human dietary component. Information concerning the chemical and fatty acid composition of freshwater fishes is valuable to nutritionists who are interested in finding sources of low-fat, high protein foods, with desirable fatty acid compositions and acceptable amount of total cholesterol.

Fish meat contains biologically active protein which is characterized by a very favourable composition of amino acids, a high omega-3 polyunsaturated fatty acid content such as eicosapentaenoic acid (20:5 n-3, EPA) and docosahexaenoic (22:6 n-3, DHA), and fat-soluble vitamins as well as it represents a good source of micro- and macro-elements (£uczyñska et al., 2006; Maqsood and Benjakul, 2010).

The shortage of α-linolenic acid (18:3 n-3, ALA) is responsible for neurological disorders and poor growth (Cundiff et al., 2007). DHA and EPA have been shown to have a positive effect in preventing hypertension and cardiovascular diseases (Kris-Etherton et al., 2002) and also have beneficial effects by improving defence

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mechanisms and by the antiinflammatory activity of long-chain n-3 PUFAs (Dorea, 2008). Essential polyunsaturated fatty acids such as ALA, EPA and DHA are not synthesized in the human body and effectively synthesized only by aquatic organisms; therefore, humans can receive these essential fatty acids by marine and freshwater fishes (Sushchik et al., 2007; Jabeen and Chaudhry, 2011).

The average per capita consumption of fish in Republic of Serbia is very low compared with other European country and in 2009 amounted 5.0 kg person^{-1}year^{-1} (Baltić et al., 2009), because of that it is inevitable to educate the consumers on fish quality and the necessity of its consumption on regular basis.

Recently, several investigations about meat quality and safety of fish from our fishponds were carried out (Trbović et al., 2009; Spirić et al., 2009; Ćirković et al., 2011, 2012), but no data is available concerning fatty acids and chemical composition of warm water fish species from free catch. Therefore, the objective of this study was to determine and compare results of the proximate and fatty acid composition of seven popular and commercial important species of freshwater fish (asp (*Aspius aspius*), common bream (*Abramis brama*), common barbel (*Barbus barbus*), common carp (*Cyprinus carpio*), sterlet (*Acipenser ruthenus*) and northern pike (*Esox lucius*)) which were hooked from the Danube river in area of Novi Sad.

Material and Methods

Fish samples

The experimental freshwater fish were obtained in natural conditions (the Danube River, area of Novi Sad) in June on the same day. Of each species catch and weight, eight fish with similar body weights were selected for analyses and stored at a temperature of –18°C. Deskinned fillets of dorsal muscle part of each fish were served as analytical material for determination of proximate composition and fatty acid profile. Fish fillets were blended (Braun CombiMax 600). To examine fatty acid content and total cholesterol samples were stored in dark plastic bags at temperatures of –18°C.

Chemical analysis

Water content of fish fillets was determined after drying the samples at 105ºC to constant weight for 24 hours (SRPS ISO 1442:1997). Crude protein content was determined by Kjeldahl method (Manual book, Kjeltec Auto 1030 Analyzer, Tecator, Sweeden) (using the common conversion factor of N x 6.25) and ash was determined after burning at 550±25 °C (SRPS ISO 936:1998). Crude lipid in fish tissue was also analyzed using the Soxhlet System with ether as solvent (SRPS ISO 1443:1997).

Extraction of Lipids by ASE

Spirić et al. (2010) have previously described Method for extraction of lipids from fish muscle by ASE. Briefly, total lipids were extracted from fish muscle tissues by accelerated solvent extraction (ASE 200, Dionex, Sunnyvale, CA). Homogenate of sample mixed with diatomaceous earth was subsequently extracted with a mixture of n-hexane and iso-propanol (60:40 v/v) in 33 ml extraction cell at 100°C and nitrogen pressure of 10.3 MPa in two cycles lasting 10 min. Then, the solvent was removed under stream of nitrogen in Dionex Solvent Evaporator 500 at 50°C until dryness. The fat extract was further used for fatty acids determination.

Fatty Acid Analysis by Capillary Gas Chromatography (CGC)

Fatty acid methyl esters (FAME) were prepared by trans-esterification using trimethylsulfonium hydroxide (SRPS EN ISO 5509:2000 procedure). The GC instrument Shimadzu 2010 (Kyoto, Japan) used for FAME determination was equipped with a split/splitless injector, fused silica cianopropyl HP-88 column (length 100 m, i.d. 0.25 mm, film thickness 0.20 μm, J&W Scientific, USA), and flame ionization detector and workstation (Shimadzu GC Solution ver. 2.3). The column, injector and detector temperature were programmed as described by Spirić et al. (2010). The carrier gas was nitrogen at a flow rate of 1.33 ml/min and injector split ratio of 1:50. Injected volume was 1 μl and analysis lasted 50.5 min. The chromatographic peaks in the samples were identified by comparing relative retention times of FAME peaks with peaks in a Supelco 37

Component FAME mix standard (Supelco, Bellefonte, USA). The contents of fatty acids in the fish muscles are expressed as the percentage of total fatty acids.

Cholesterol Determination

Direct saponification method (Maraschiello et al., 1996) has been used for cholesterol determination in fish muscle. In short, cholesterol in fish fillets (from dorsal body parts) was measured using HPLC/PDA system (Waters 2695 Separation module/Waters photodiode array detector, USA), on a Phenomenex Luna C18 (2) reverse phase column, 150 mm x 3.0 mm, 5µm particle size, with C18 analytical guard column, 4.0 x 2.0 mm (Bligh and Dyer, 1959). Detection was performed at 210 nm and total analysis time lasted 10 min.

Statistical analysis

The results presented for fish of particular species are means ± S.E.M. obtained in the analysis of 8 fish. The differences between the mean values of parameters examined (proximate composition and fatty acid composition) were calculated using one-factor analysis of variance (ANOVA). Use was also made of the Tukey HSD test and statistically significant differences were reported at $P < 0.01$. Calculations were made with the use of Statistica 8.0 software (Statistica 8, StatSoft Inc., Tulsa, USA).

Results

Average body weight of experimental fishes: asp (*Aspius aspius*), common bream (*Abramis brama*), common barbel (*Barbus barbus*), common carp (*Cyprinus carpio*), sterlet (*Acipenser ruthenus*) and northern pike (*Esox lucius*) was 1220, 1230, 870, 1420, 1320 and 1480 g, respectively.

Table 1 summarizes chemical composition and cholesterol content of fish samples. The amount of protein was the highest in the fillets of barbel (18.61 g/100 g), without significant difference with protein content in the flesh of pike and asp ($P > 0.01$) and the lowest in common carp fillets (16.69 g/100 g). Fat ranged from 1.61 g/100g in the muscles of pike to 7.78 g/100g in the muscles of barbell and there was significant difference in fat content of all examined fish ($P < 0.01$). Results of ash content in fishes flesh also showed statistically significant difference between species, except for common carp and sterlet. The total cholesterol content was highly variable, being the highest in the sterlet fillets (73.59 mg/100 g) and the lowest in asp (36.26 mg/100 g) and variation was statistically significant between fishes ($P < 0.01$).

A lipid analysis enabled the classification and quantitative determination of 21 fatty acids and besides that the sum of saturated fatty acids (SFA), monounsaturated fatty acids (MUFA), polyunsaturated fatty acids (PUFA), n-3 acids, n-6 acids, n-3/n-6 ratio, n-6/n-3 ratio and ratio of PUFA/SFA, as well as ratio of USFA/SFA which represent the indicators of lipid quality (Table 2). The total amount of saturated fatty acids (SFA) was the highest in pike (39.9%) and the lowest in bream (27.27%). Individual SFA were variable by species. Palmitic acid (C16:0) was predominant in all species, whereas arachidic acid (C20:0) was the least SFA in samples. Caprylic acid (C8:0) was detected in fat of asp, common bream, and pike and percentage of these fatty acid was higher in this species with regard to pentadecylic acid (C15:0), margaric acid (C17:0) and arachidic acid (C20:0), while, in barbell, carp and sterlet C8:0 was not detected. The most abundant MUFA was oleic acid (C18:1, n-9), ranging from 17.70% in pike to 32.11 % in bream, followed by palmitoleic acid (C16:1, n-7) and vaccenic acid, C18:1cis-11 (Table 2). The MUFA proportion was the lowest in pike (31.66%) and greatest in bream (56.09%). Pike had the highest (28.15%), while bream had the lowest (17.07%) PUFA proportion. Asp, which is also carnivorous like a pike had high PUFA content (27.99%). Samples were also highly variable in terms of n-3 and n-6 contents (Table 2), for instance the n-3/n-6 ratio was the lowest in common carp (0.44), whereas it was the greatest in sterlet (2.9). Similarly, the PUFA/SFA, an indicator of the quality of lipids, was the least favourable in bream (0.63) and the most favourable in barbel (0.92).

Discussion

The flesh obtained from the experimental fishes was characterized by a varied content of fat and water. The same regularity was observed by Belinsky et al. (1996);

£uczyñska et al. (2008) and Ćirković et al. (2012). The varied content of fat was compensated by the content of water, which is in agreement with the results obtained by Żmijewski et al. (2006) who found a reverse correlation between the fat and water contents, which is common for many fish species.

According to the present results the asp and bream tissue contained significantly higher amount of fat in comparison with pike, which is consistent with results obtained by Żmijewski et al. (2006) for the same species despite that in the present research fat content in pike was more than twofold higher, although average body weight of examined pike was only about 200 g higher in the present research. The bream caught in the waters of Greece had 1% lipid (Aggelousis and Lazos (1991), and similar values were found in the study of £uczyñska et al. (2008), while in the present study the bream had higher lipid content (3.24 g/100 g). The percentage of total lipid in pike from Canada was 0.4% (Belinsky et al., 1996), whereas the content of total lipid for pike examined by £uczyñska et al. (2008) was 0.56%. The analysis of meat quality conducted by Jankowska et al. (2008) indicated that the cultured pike fillets contained in excess of 11-fold more fat in comparison with the wild pike (2.40% compared with 0.19%). Other studies have noted, however, that the fat content of wild pike specimens with a higher body weight (BW 1248.0 g) that were also caught in Poland during the summer season was 0.64% (Żmijewski et al., 2006) and in the present research the fat content was 1.61 g/100 g (BW 1480g). Pike and asp contained significantly higher content of protein compared with bream (Table 1), while in research conducted by Żmijewski et al. (2006) there was no statistically significant difference, but the amount of protein was the lowest in fillets of bream. The present results of proximate composition of common carp, pike and common bream are quite similar with the results of Bud et al. (2008), where fishes were obtained from aquaculture and no data was given about age or body weight of fishes. Lipid content of sterlet was 5.39 g/100 g and it was close to the lowest value (5–15%) reported for cultured sturgeon species (Badiani et al., 1997). Water content of sterlet was somewhat lower (75.38 g/100 g vs 77.5–77.2), protein content was higher (17.54 g/100 g vs 13.1–13.8), while lipid content was within range 4.8–6.1 g/100 g compared with results obtained by Lee et al (2012) for cultured sterlet. It has been reported that under culture conditions, fish muscle contains more lipid than in the wild (Cahu et al., 2004). This is supported by data presented by Jankowska et al. (2008) who reported higher lipid content for cultured northern pike compared to the wild pike. Interesting fact is that common carp from the free catch had fat content 7.1 g/100 g (Table 1) which is much higher compared with cultured carp (Ćirković et al., 2011; 2012), exception is cultured carp fed with grains with fat content between 10–15%. That confirms that proximate composition of common carp highly depends of diet (Steffens and Wirth, 2007). Significant differences in the content of ash, which was the lowest (0.63 g/100g) in pike and the highest (1.31 g/100 g) in barbel may be due to the presence of small bones in fish fillets. Namely, the calcium, which released during bone demineralization, can contribute to a greater mass fraction of ash in the total chemical composition of fish meat.

Table 1
Proximate composition of seven freshwater fish species from the Danube

Parameters	Asp	Common bream	Common barbel	Common carp	Sterlet	Northern pike
Water content, g/100 g	78.51 ± 0.2b	78.66 ± 0.19ab	72.39 ± 0.29e	73.73 ± 0.24d	75.38 ± 0.35c	79 ± 0.14a
Protein content, g/100 g	18.07 ± 0.09a	17.59 ± 0.22b	18.61 ± 0.37a	16.69 ± 0.4c	17.54 ± 0.23b	18.43 ± 0.21a
Fat content, g/100 g	2.78 ± 0.11e	3.24 ± 0.15d	7.78 ± 0.15a	7.13 ± 0.1b	5.39 ± 0.14c	1.61 ± 0.06f
Ash content, g/100 g	1.16 ± 0.05b	0.80 ± 0.04d	1.33 ± 0.03a	0.88 ± 0.05c	0.93 ± 0.09c	0.64 ± 0.03e
Cholesterol content, mg/100g	36.26 ± 0.17e	41.93 ± 0.15d	53.12 ± 0.05b	45.43 ± 0.14c	73.59 ± 0.11a	36.37 ± 0.13e

(Data are means ± S.E.M. (n = 8). Different superscripts within the same rows differ ($P < 0.01$))

According to Andrade et al. (1995), the most dominant saturated acids in freshwater fish from south Brazil were palmitic (C16:0) and stearic (C18:0), whereas palmitoleic (C16:1) and oleic (C18:1) acids were the major component among monounsaturated fatty acids. Among saturated and monounsaturated acids in the most fish studied, oleic acid was the highest, followed by palmitic and palmitooleic acid (Table 2). £uczyñska

Table 2
Fatty acid composition of seven freshwater fish species from the Danube

Fatty acids,%	Asp	Common bream	Common barbel	Common carp	Sterlet	Northern pike
C8:0	1.23 ± 0.08^{b}	1.33 ± 0.07^{b}	0^{c}	0^{c}	0^{c}	3.64 ± 0.31^{a}
C14:0	1.93 ± 0.09^{d}	1.94 ± 0.14^{d}	4.16 ± 0.07^{a}	2.87 ± 0.1^{c}	3.31 ± 0.27^{b}	1.71 ± 0.12^{d}
C15:0	0.42 ± 0.05^{c}	0.37 ± 0.04^{c}	0.70 ± 0.08^{a}	0.56 ± 0.09^{b}	0.66 ± 0.05^{ab}	0.76 ± 0.07^{a}
C16:0	18.23 ± 0.28^{e}	18.75 ± 0.19^{d}	19.45 ± 0.19^{c}	19.4 ± 0.2^{c}	25.09 ± 0.14^{b}	26.10 ± 0.19^{a}
C16:1	10.43 ± 0.14^{e}	14.96 ± 0.19^{b}	15.96 ± 0.13^{a}	13.84 ± 0.14^{c}	13.27 ± 0.12^{d}	7.76 ± 0.15^{f}
C17:0	0.74 ± 0.12^{b}	0.52 ± 0.05^{c}	0.95 ± 0.09^{a}	0.71 ± 0.13^{b}	1.09 ± 0.14^{a}	1.18 ± 0.11^{a}
C18:0	5.2 ± 0.08^{b}	4.13 ± 0.08^{c}	3.22 ± 0.15^{d}	3.91 ± 0.17^{c}	2.38 ± 0.12^{e}	6.37 ± 0.19^{a}
C18:1cis-9	27.4 ± 0.27^{c}	32.11 ± 0.2^{a}	20.24 ± 0.21^{e}	30.20 ± 0.17^{b}	24.87 ± 0.15^{d}	17.70 ± 0.22^{f}
C18:1cis-11	8.34 ± 0.28^{a}	8.27 ± 0.16^{a}	7.38 ± 0.11^{b}	7.17 ± 0.14^{bc}	7.05 ± 0.16^{c}	5.51 ± 0.12^{d}
C18:2, ω-6	6.5 ± 0.13^{b}	3.52 ± 0.21^{c}	6.23 ± 0.12^{b}	8.79 ± 0.32^{a}	2.8 ± 0.19^{d}	8.76 ± 0.23^{a}
C18:3,ω-6	0.16 ± 0.02^{b}	0.1 ± 0.02^{b}	0.17 ± 0.04^{b}	0.23 ± 0.36^{b}	0.69 ± 0.51^{a}	0.2 ± 0.01^{b}
C18:3, ω-3	2.20 ± 0.15^{d}	2.19 ± 0.15^{d}	3.35 ± 0.19^{b}	2.71 ± 0.11^{c}	4.34 ± 0.1^{a}	2.56 ± 0.16^{c}
C20:0	0.23 ± 0.07^{a}	0.22 ± 0.03^{a}	0.15 ± 0.04^{b}	0.14 ± 0.03^{b}	0.14 ± 0.04^{b}	0.15 ± 0.04^{b}
C20:1	1.53 ± 0.08^{a}	0.75 ± 0.13^{b}	1.68 ± 0.16^{a}	1.74 ± 0.09^{a}	0.77 ± 0.11^{b}	0.68 ± 0.12^{b}
C20:2	0.86 ± 0.1^{b}	0.68 ± 0.08^{c}	0.50 ± 0.03^{d}	1.52 ± 0.1^{a}	0.47 ± 0.07^{d}	0.85 ± 0.13^{b}
C20:3, ω-6	0.52 ± 0.11^{b}	0.28 ± 0.11^{c}	0.27 ± 0.08^{c}	0.76 ± 0.12^{a}	0.2 ± 0.11^{c}	0.45 ± 0.05^{b}
C20:3, ω-3	0.74 ± 0.11^{a}	0.42 ± 0.06^{bc}	0.5 ± 0.07^{bc}	0.38 ± 0.08^{c}	0.55 ± 0.05^{b}	0.46 ± 0.08^{bc}
C20:4, ω-6	2.71 ± 0.12^{b}	2.18 ± 0.05^{d}	1.48 ± 0.06^{e}	2.42 ± 0.09^{c}	1.54 ± 0.08^{e}	3.85 ± 0.14^{a}
C20:5, ω-3	3.09 ± 0.11^{d}	3.94 ± 0.11^{c}	5.41 ± 0.1^{a}	1.36 ± 0.08^{f}	4.93 ± 0.09^{b}	1.94 ± 0.08^{e}
C22:5, ω-3	2.61 ± 0.16^{b}	1.18 ± 0.09^{d}	2.85 ± 0.1^{a}	0.65 ± 0.05^{e}	2.86 ± 0.04^{a}	1.51 ± 0.1^{c}
C22:6, ω-3	5.22 ± 0.1^{c}	2.58 ± 0.16^{e}	5.55 ± 0.09^{b}	0.87 ± 0.08^{f}	3.79 ± 0.09^{d}	7.58 ± 0.26^{a}
SFA	27.99 ± 0.29^{d}	27.27 ± 0.24^{d}	28.63 ± 0.27^{c}	27.59 ± 0.19^{d}	32.67 ± 0.34^{b}	39.9 ± 0.33^{a}
MUFA	47.69 ± 0.37^{c}	56.09 ± 0.34^{a}	45.27 ± 0.3^{e}	52.94 ± 0.18^{b}	45.97 ± 0.15^{d}	31.66 ± 0.3^{f}
PUFA	24.60 ± 0.3^{c}	17.07 ± 0.27^{f}	26.31 ± 0.27^{b}	19.7 ± 0.49^{e}	22.17 ± 0.37^{d}	28.15 ± 0.24^{a}
ω-6	10.75 ± 0.22^{b}	6.76 ± 0.18^{d}	8.65 ± 0.13^{c}	13.73 ± 0.42^{a}	5.7 ± 0.36^{e}	14.11 ± 0.24^{a}
ω-3	13.85 ± 0.22^{c}	10.31 ± 0.22^{d}	17.66 ± 0.18^{a}	5.97 ± 0.16^{e}	16.47 ± 0.05^{b}	14.04 ± 0.35^{c}
ω-3/ω-6	1.29 ± 0.03^{d}	1.53 ± 0.06^{c}	2.04 ± 0.03^{b}	0.44 ± 0.02^{f}	2.9 ± 0.19^{a}	1 ± 0.04^{e}
ω-6/ω-3	0.78 ± 0.02^{c}	0.66 ± 0.02^{d}	0.49 ± 0.01^{e}	2.30 ± 0.08^{a}	0.35 ± 0.02^{f}	1.00 ± 0.04^{b}
PUFA/SFA	0.88 ± 0.01^{b}	0.63 ± 0.01^{e}	0.92 ± 0.01^{a}	0.71 ± 0.02^{c}	0.68 ± 0.01^{d}	0.71 ± 0.01^{c}
USFA/SFA	2.58 ± 0.03^{c}	2.68 ± 0.02^{a}	2.5 ± 0.03^{d}	2.63 ± 0.03^{b}	2.09 ± 0.03^{e}	1.5 ± 0.02^{f}

(Data are means ± S.E.M. (n = 8). Different superscripts within the same rows differ ($P < 0.01$), USFA – unsaturated fatty acids, SFA – saturated fatty acids, MUFA – monounsaturated fatty acids, PUFA – polyunsaturated fatty acids)

et al. (2008) found that the palmitic (22.2%) and stearic (10.98%) acids were the dominant component among saturated acids in muscle lipids of pike from lakes, which complies with the present results for pike. The content of oleic acid (17.70%) observed in the present research was higher than the content of this acid in the pike examined by £uczyñska et al. (2008), which results in higher amount of total monounsaturated fatty acid in this species in the present study. The percentage of EPA and DHA in bream caught in the waters of the Greece (Aggelousis and Lazos, 1991) and Poland (£uczyñska et al., 2008) was higher than other n-3 polyunsaturated fatty acids. The present study confirmed the findings of these authors. Notwithstanding, pike fat contained the highest percentage of SFA, the total sum of SFA in 100g of carcass was lower than in carcass of bream and asp owing to lower percentage of fat in flesh of pike and this is in agreement with observation of Żmijewski et al. (2006). Among the reports dealing with the fatty acid composition in various species of the genus Barbus (Zenebe et al., 1998; Uysal et al., 2008; Aras et al., 2009), the total amount of PUFAs in muscles of this genus varies from 10 to 57%, with EPA varying from 0.7 to 11%, and DHA from 0.6 to 20%, which is consistent with the present results for common barbel. The analysis of fatty acid composition conducted by Jankowska et al. (2008) indicated that the percentage of fatty acid of various saturated fatty acids (SFA) in cultured and wild pike varied; the exception was palmitic fatty acid, which occurred in the greatest quantities; the sum of total MUFA in the fillets of cultured pike was nearly twofold higher than in wild pike (30.90% compared with 15.97%); the quantity of PUFA in cultured pike was lower than that determined in the wild pike (42.04% compared with 58.33%); cultured pike contained less n-3 PUFA (32.42% compared with 41.26%) and n-6 PUFA (6.47% compared with 15.79%). Almost all freshwater species, with the exception of pike, contained higher amounts of monounsaturated fatty acids (MUFA) than saturated fatty acids which is in compliance with results found by £uczyñska et al. (2008) for bream and pike. According to £uczyñska et al. (2008) the MUFA ranged between 13.95% (pike) and 33.44% (bream). In the present study, the amount of monounsaturated fatty acids was higher and ranged between 31.6% (pike) and 56.09% (bream). The relative contents of n-3 PUFA (10.31–17.66%) was higher than the n-6 polyunsaturated fatty acids containing from 6.76 to 14.11%, except for common carp, which is in a line with results noted by £uczyñska et al. (2008) for fresh water fishes. A lower value of saturated fatty acids (SFA) was noted in non-predatory than in predatory fish by £uczyñska et al. (2008) which is confirmed in the present research for pike, but not for asp. Aggelousis and Lazos (1991) and £uczyñska et al. (2008) found out somewhat higher amounts of total saturated and total n-3 and n-6 polyunsaturated and total polyunsaturated fatty acids and lower amount of total monounsaturated fatty acids in bream to those observed in the present study. Ćirković et al. (2011) found that it is possible to influence the fatty acids composition of lipids through rearing conditions, particularly feed type. According to research conducted by Buchtová et al. (2010) and Ćirković et al. (2012), cultured carp grown on natural food had a high content of both n6 and n3 fatty acids and Ćirković et al. (2011) observed that PUFA/SFA ratio was the most favourable in carp fed complete food, and the least in carp fed with maize and wheat. USFA/SFA ratio was also the best in carp fed a complete feed mixture.

Bieniarz et al. (2000) found that freshwater carnivorous fish can be characterized by greater n-3/n-6 fatty acid ratio than phytophagous and benthophagous cyprinoid fish, which was not consistent with the present results because pike and asp, that is only carnivorous cyprinid fish feeding on small fish (Brylińska, 1986) had lower n-3/n-6 ratio than other experimental fish, except of common carp. However, from the nutrition viewpoint it should be considered the content of fat in fish meat, because when the values of PUFAs expressed per 100 g of fish meat, intake of n-3 PUFAs is larger when human consume fishes that contain higher amounts of fat than lean fish (Cahu et al., 2004; Lichtenstein et al., 2006).

Wood et al. (2008) have suggested that ratio of PUFA/SFA should be above 0.4 and according that all examined fish species have had favourable (from 0.63 to 0.92) PUFA/SFA ratio. The n-6/n-3 ratio in all examined fishes was in the optimal range of 2/1–4/1 for human health as suggested by Pepping (1999).

The knowledge about cholesterol content in food is important, especially in fish meat, because consumption of fish is currently increasing based on the recommendations of healthy nutrition. Cholesterol content in female and male carp fillets was in range 69.4 mg/100 g – 77.6 mg/100 g (Komprda et al., 2003). Trbović et al. (2009) reported that the amount of total cholesterol was 48.9 mg/100 g in one-year old carp in April and 54.3 mg/100 g in the same age samples harvested in June. In the study implemented by Ćirković et al. (2012), cholesterol level was 55.8 mg/100 g in 2-year old carp. In agreement literature, cholesterol content in carp muscle tissue varied considerably from 38 to 120 mg/100 g, depending on fish breed and age, husbandry system, and harvest season (Bieniarz et al., 2001; Ćirković et al., 2011). Kopicová and Vavreinová (2007) detected the content of total cholesterol in common carp, sterlet, northern pike and asp and it amounted 47, 61, 86 and 45 mg/100 g, respectively. Piironen et al. (2002) reported slightly higher cholesterol content in most analyzed fish species (49–92 mg/100 g) in comparison with meat of terrestrial animals (45–84 mg/100 g). The pike used in the study conducted by Kandemir (2012) had an average weight of 1457 g and the amount of cholesterol found in tissue was 146.4 mg/100 g. Ćirković et al. (2012) found out that the difference between six freshwater fishes with respect to the amount of cholesterol detected in muscle tissue was significant and detected the level of total cholesterol in range from 34.34 mg/100 g in catfish to 62.32 mg/100g in silver carp. Research conducted by Moreira et al. (2001) on the cholesterol content of many freshwater fish species showed that the values ranged between 40.99 and 52.79 mg/100 g. According to Luzia et al. (2003) the amount of total cholesterol in freshwater fish is lower in comparison with marine fish. The daily intake of cholesterol is currently recommended not to exceed 300 mg (James and Ralph, 2000). It can be argued that mentioned freshwater fish in the present study are well-favoured sources of cholesterol.

Stansby (1973) pointed out that fish should be included in diets for at least three reasons: as a general source of nutritional components; as low fat, high protein food; and as source of polyunsaturated fatty acids, which is confirmed in the present study. At the same time, the recommended ratio of polyunsaturated fatty acids (PUFA) to saturated fatty acids (PUFA/SFA) should be increased to above 0.4 (Wood at al., 2003). Since some meats of terrestrial farmed animals naturally have a PUFA/SFA ratio of around 0.1 (Wood et al., 2008), meat has been implicated in causing the imbalanced fatty acid intake of today's consumers. Fish lipids are particularly rich of polyunsaturated fatty acids (PUFA) that are only slowly synthesized in humans which is the major difference between meat of fish and meat of farmed terrestrial animals (Vladau et al., 2008). The n-3/n-6 ratio was found generally lower in cultivated than in wild fish (Orban et al., 2003). This is due to the fact, that the diet source of protein is cheaper than fishmeal (Shearer 2001). The recommended the ratio of n-6/n-3 should be less than 4 (Scollan et al., 2006) and this ratio in some meats of terrestrial animals is higher than this (Wood et al., 2003).

However, it is difficult to rank examined fishes from best to worst from the point of view of human nutritive value. The fat content in fish tissue contributes to its organoleptic properties, texture and flavour. Fat, rich tissue is juicy, while lean tissue is dry and perceived as thickly fibrous (Żmijewski et al., 2006) On the other hand, there are certain groups of people who require meat with minimal fat and cholesterol content.

Conclusion

The importance of the obtained results lies in the fact that, up to now, there were no data on meat quality of freshwater fish species from the Danube River in Serbia region, therefore it can be valuable information to ecologists, environmentalists, nutritionists, food scientist and other scientist.

The meat of warm water fish from the Danube River represents valuable source of healthy nutrition for the consumer. Chemical and fatty acid composition varied between different species and among the same species. All examined species have had PUFA/SFA ratio higher than 0.4, and n–6/n–3 ratio was lower than 4 which are the prescribed values recommended from WHO/FAO organization. The potential of exploiting presently insufficiently used freshwater species for developing

high-protein foods for market and for introducing as a new species in aquaculture, underscore the need for reliable analytical data.

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