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RESEARCH PAPER

Comparison of Fatty Acids in the Muscles and Liver of Pond-Cultured and Wild Perch, *Perca fluviatilis* (L.), in Poland

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Abstract

This study investigated the fatty acid composition of Eurasian perch, (*Perca fluviatilis* L.) from pond polyculture with (White Rawska), and populations from Lakes Mosąg and Wadąg. The eicosapentaenoic fatty acid EPA in muscles of the examined groups did not differ (P>0.05). A lower content of eicosapentaenoic fatty acid was noted in the liver of perch from Lake Mosąg than the other fish examined (P≤0.05). Docosapentaenoic fatty acid DHA content in the liver of perch from Lake Wadąg (23.03%) and the pond-cultured perch were higher than in the perch from Lake Mosąg (P≤0.05). The pond-cultured perch (P≤0.05) had significantly lower content of docosapentaenoic fatty acid in muscles. The muscles of perch from Lake Wadąg (38.61%) contained more n-3 polyunsaturated fatty acid PUFA than the other studied fish (P≤0.05), whereas the liver of fish from this lake (32.32%) and pond (33.73%) had higher values of n-3 polyunsaturated fatty acid PUFA than perch from Lake Mosąg (24.62%) (P≤0.05). Fish had a higher content of n-3 polyunsaturated fatty acid than n-6 and low levels of fat and may be an important dietetic fish food from a consumer health point of view.

Keywords: fat; fatty acids, liver; muscle tissue, perch.

Introduction

Civilization diseases such as cardiovascular disease, dyslipidaemias, diabetes, osteoporosis, inflammatory and cancer are all related to dietary factors (Benatti *et al*., 2004). According to Achremowicz and Szary-Sworst (2005), the fatty acids is special important in the diet. Therefore, polyunsaturated fatty acids (PUFA) from the n-3 and n-6 series have an influence on the nutritional quality of fish Fatty acids from the n-3 series: α-linolenic acid (C18:3, ALA), EPA (eicosapentaenoic,C20:5) and DHA (docosapentaenoic, C22:5) (Nestel, 2000, Kolanowski and Laufenberg, 2006, Sanchez-Villegas *et al*., 2007, DeFilippis *et al*., 2010) have potential beneficial human health effects. The basic fatty acid from the n-6 family is linoleic acid (C18:2, LA) which is a precursor to the other main n-6 PUFA that is arachidonic acid (C20:4 n-6, AA) (Holub and Holub, 2004, Steffens and Wirth, 2005). A plant-derived acid, ALA, is a precursor to EPA and DHA (Williams and Burdge, 2006, Lecerf, 2007). These fatty acids must be ingested with food. LA and ALA cannot be synthesized in an animal organism and biosynthesis takes place only in the vegetable kingdom (Cichoń, 2003).

Eurasian perch (*Perca fluviatilis* L.), as well as other fish, such as common carp (*Cyprinus carpio* L.), rainbow trout (*Oncorhynchus mykiss* Walb.), European eel (*Anquilla anquilla* L.), Nile perch (*Lates niloticus* L.), the catfish (*Pangasius sp.*), Nile tilapia (*Oreochromis niloticus* L.), northern pike (*Esox lucius* L.), sturgeon (*Acipenser* sp.). and pike-perch (*Sander lucioperca* L.), are one of the most popular and important freshwater species in Europe. The flesh of this fish is white with a small flaky, delicate structure and mild flavour (Watson, 2008). Eurasian perch smaller than 10 cm feed on plankton and small invertebrates, whereas large perch is a top predator (Szczerbowski, 1995). According to Orban *et al*. (2007), the lipid muscles of perch are characterized by a high proportion of n-3 PUFA, ascribable to the predatory feeding habit of this fish. Kołakowska *et al*. (2003) reported that the compositions of lipids and fatty acids in aquatic organisms depend on external factors such as temperature, salinity or food availability and internal factors, including species, sex and physiological status (gonad maturity, condition, age). Another important factor which has an impact on the composition of fatty acids is diet (Hunter *et al*., 2000, Cahu *et al*., 2004). Hossain (2011) noted that as long as fish are raised under appropriate conditions

and dietary regime, farmed fish can provide consumers with a nutritional composition that is at least as beneficial as that provided by wild fish. Farmers can control and manipulate different stages of the rearing, feeding and processing steps to deliver a designer yellow perch (*Perca flavescens*) to consumers with desired quality and nutritional compositions (Gonzalez *et al*., 2006). However, in terms of EPA and DHA, the reared perch is not inferior to wild perch. (Jankowska *et al*., 2010). On the other hand, perch reared in an extensive pond in a polyculture with carp and tench (*Tinca tinca* L.) is as good as intensively-cultured perch as a source of DHA and EPA (Stejskal *et al*., 2011). Consequently, the aim of the study was to investigate the lipid content and fatty acids composition in perch (*Perca fluviatilis* L.) from extensive pond (fed natural food) in polyculture with common carp and wild perch (in a lake), and to determine differences in the profile of fatty acids between groups of fish inhabiting different aquatic ecosystems (flow Lake Mosąg on the river Łyna, Lake Wadąg and pond). .

Materials and Methods

Sample Preparation

Eurasian perch (*Perca fluviatilis* L.) were caught in November 2011 from flow Lake Mosąg on the river Łyna (n=7) and in December from Lake Wadąg (n=6) (North-East Poland) and the Żurawia pond near White Rawska (n=8) (Central Poland). They were euthanized and the body weight (±0.1 g) and total length (±0.1 cm) were measured (Table 1). After euthanizing, fillets and liver were dissected and stored in labelled bags in a freezer at -40°C until analysis. Each sample was prepared from muscles and liver taken from one specimen. Fish from all stock were fed with natural food like small prey fish, mainly perch and roach. The population from the lakes were also fed bream and tench.

Proximate Composition

Approximately 1g sample (±0.0001 g) in duplicate were dried to a constant weight at 105°C in glass sample tubes with frits and transferred to weighed beakers. The lipids from the fish muscles (without skin) and liver were extracted according to the hot extraction method using an E-816HE automatic extractor. The analysis consisted of 3 steps (extraction, rinsing, drying). After the extraction was finished, all of the solvent (petroleum ether) was collected in the tank. Fat was dried in beaker at 100°C to a constant weight and then weighed (PN-67/A-86734, 1967, http://www.donserv.pl/imagesdb_dane-techniczne-140331-2.pdf).

The content of fat (%) was calculated according to pattern: x = [(b - a) X 100]/ c, where, a = weight of flask (g), b = weight of flask with extracted fat (g), c = weight of samples (g)

Protein content was determined following the method of Kjeldahl (with a conversion factor of 6.25) (PN-75/A-04018, 1975). In the case of ash, samples (about 1g±0.0001 g) were dry-digested at 600°C for 6 h in quartz tests and were then weighed (Krełowska-Kułas, 1993).

Fatty Acids Analysis

In the fatty acid analysis, lipids were extracted with the use of Folch's procedure (Christie, 1973). Therefore, the studied material was broken up and mixed. 2 g of sample was homogenised for 1 min with 20 ml of methanol. Next, 40 ml chloroform was added

Table 1. The biometric parameters of fish and composition **(**%) of muscles and liver of perch studied (mean±SD)

	Extensively-cultured Perch		Wild Perch
	Pond (n = 8)	Lake Mosąg (n = 7)	Lake Wadąg (n = 6)
Weight (g)	101.6-634.0 286.4±165.7	376.2-595.8 447.4±75.5	350.0-719.5 508.8±155.0
Total Length (cm)	19.5-34.5 25.9±4.6	28.5-34.5 31.0±1.8	29.5-36.5 33.0±3.2
Age	5+ - 8+	7+ - 8+	8+ - 10+
Main Food	roach, perch	roach, tench, bream, perch	roach, bream, perch
Muscles			
Total Fat	0.61±0.36^{a}	0.50±0.38^{a}	0.49±0.42^{a}
Protein	19.08±1.72^{a}	17.66±1.56^{a}	18.49±2.14^{a}
Ash	1.04±0.46^{a}	1.41±0.33^{a}	1.01±0.15^{a}
Water	81.31±1.00^{a}	79.94±1.10^{b}	81.17±0.87^{a}
Liver			
Total Fat	1.39±0.58^{a}	1.02±0.60^{a}	0.76±0.56^{a}
Protein	19.14±1.42^{a}	17.62±1.52^{a}	17.37±2.53^{a}
Ash	0.79±0.79^{b}	1.66±0.27^{a}	1.36±0.26^{ab}
Water	77.06±2.75^{a}	77.17±1.32^{a}	78.88±0.84^{a}

SD–Standard Deviation; a, b – significant difference (P≤0.05). The same letter indicates the absence of significant differences between extensively-cultured and wild perch.

and the procedure was continued for 2 min. The prepared mixture was filtered to a 250 ml glass cylinder. The solid residue was re-suspended in 60 ml chloroform : methanol (2:1 v/v) and homogenized again for 3 min. After filtering, the solid was washed once more with 40 ml chloroform and once with 20 ml methanol. The combined filtrate was transferred to the same cylinder. 0.88% sodium chloride in water (determining ¼ volume of filtrate) was added to the total filtrate and then shaken and left overnight. The upper layer was removed and to the lower layer a water : methanol mixture (1:1 v/v) was added and the washing procedure was repeated. The remaining layer was trickled by anhydrous sodium sulphate and distilled by means of aggregate for distillation of solvents.

The fatty acid methyl esters were prepared from total lipids with the Peisker method with chloroform:methanol: sulphuric acid (100:100:1 v/v) (Żegarska *et al*., 1991).

The fatty acids of methyl esters of each sample were analysed with capillary gas chromatography (chromatograph 7890A Agilent Technologies) with a flame-ionization detector (FID) under the following conditions: capillary column (dimension 30 m x 0.25 µm with a 0.32 mm internal diameter, liquid phase Supelcowax 10), temperature: flame-ionization detector – 250°C, injector – 230°C, column – 195°C, carrier gas–helium with a flow rate 1.5 ml/min. Individual fatty acids were identified by comparing the relative retention time peaks to the known Supelco's standards of fatty acids.

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Statistical Analysis

Significant differences in the fat, protein, ash and profile of fatty acids in the muscle and liver lipids of fish with different feeding strategies (cultured and wild perch) were investigated using ANOVA Analysis of Variance. Significant means among the three groups of fish were compared by a post-hoc Duncan's test at $\alpha = 0.05$ using STATISTICA 9.1. The data are presented as Mean ± Standard Deviation (SD).

Results

The content of fat, protein, ash and water are in Table 1, while the percentage of the sum of fatty acids and some fatty acids are given in Table 2 and Table 3. The percentage differences of saturated fatty acid (SFA) in muscle lipids were not significant between pond-cultured and wild perch from both populations ($P>0.05$), although perch liver from flow Lake Mosąg had significantly higher contents than pond perch ($P\leq0.05$). The percentages of monounsaturated fatty acid (MUFA) varied between 19.06 (perch from Lake Wadąg) and 22.65% (perch from pond) for muscles. In the case of liver, the contents of MUFA were from 20.79% (perch from a pond) to 25.64% (perch from Lake Mosąg). There were no significant differences in the MUFA between the examined fish groups ($P>0.05$). Palmitic acid C16:0 generally predominated in the saturated fatty acid group (Table 4 and Table 5). The differences in palmitic acid levels in muscles of pond fish from Lake Mosąg and Lake Wadąg (22.56%, 22.60% and 23.06%, respectively) were not significant ($P>0.05$) The livers of wild fish from Lake Mosąg (25.22%) had more of this fatty acid than perch from Lake Wadąg (21.53%) and pond perch (21.37%) with $P\leq0.05$. The most abundant mono-unsaturated fatty acid in all studied fish was oleic acid C18:1 (Table 4 and Table 5).The percentage of oleic acid in the muscle tissue of pond-cultured fish was only significantly higher (15.4%) than wild perch from Lake Wadąg (12.56%). The muscles of perch from Lake Mosąg had 14.08% of this fatty acid. In turn, no differences were observed in the content of oleic acid in the livers of perch from a pond (14.17%), Lake Mosąg (15.75%) and Lake Wadąg (13.81%) ($P>0.05$).

All studied fish had more n-3 PUFA than n-6 PUFA. The perch muscles from Lake Mosąg (13.01%) had a significantly higher content of n-6 PUFA than muscle tissue of perch from Lake Wadąg (10.51%). For pond-cultured perch, the n-6 PUFA (12.44%) levels were not significant ($P>0.05$). Similarly, significant differences in Σn-6 PUFA in the livers of the fish group were not observed ($P>0.05$). The muscles of perch from Lake Mosąg had a significantly higher content of this group of fatty acid. The muscles of wild perch from Lake Wadąg (38.61%) contained significantly more n-3 PUFA than other fish studied ($P\leq0.05$), whereas livers of fish from this lake (32.32%) and pond (33.73%) had significantly higher values of n-3 PUFA than perch from Lake Mosąg (24.62%) ($P\leq0.05$).

Arachidonic acid (AA) was the dominant n-6 polyunsaturated fatty acid. Only the AA levels between muscles of pond-cultured perch (5.70%) and muscles of perch from Lake Mosąg (7.44%) and Lake Wadąg (6.81%) were statistically significant ($P\leq0.05$). There were no significant differences in AA between the livers of the studied fish group ($P>0.05$). EPA and DHA were the predominant n-3 polyunsaturated fatty acid. The amount of EPA in the muscle tissue of the three groups did not differ significantly ($P>0.05$). A significantly lower content of EPA was noted in the livers of perch from Lake Mosąg (2.93%) than the other examined fish ($P\leq0.05$). The values of DHA in perch livers from Lake Wadąg (23.03%) and a pond (23.05%) were significantly higher than those reported for perch caught from Lake Mosąg (18.12%) ($P\leq0.05$). For the DHA levels in muscles of the studied fish, significantly lower contents of this group were found in pond perch (18.21%) ($P\leq0.05$).

The n-3/n-6 ratio in muscles and liver lipids of the studied perch ranged from 2.65 to 3.70 and from 1.8 to 2.51. The muscles of perch from Lake Wadąg

Table 2. Fatty acid contents (% of total fatty acids) in the muscle lipids of perch studied (mean±SD)

Fatty Acid	Extensively-Cultured Perch		Wild Perch
	Pond (n = 8)	Lake Mosąg (n = 7)	Lake Wadąg (n = 6)
C18:2(n-6) LA	4.64±1.83[a]	3.11±0.52	1.88±0.30[b]
C20:4(n-6) AA	5.7±0.95[b]	7.44±0.80[a]	6.81±0.78[a]
C18:3(n-3) ALA	3.83±0.91[a]	1.66±0.29[b]	1.76±0.63[b]
C20:5(n-3)EPA	7.71±1.07[a]	6.14±0.81[a]	7.81±2.69[a]
C22:5(n-3) DPA	2.72±0.56[a]	2.92±0.46[a]	2.58±0.31[a]
C22:6(n-3)DHA	18.21±1.81[b]	22.71±3.42[a]	24.94±2.94[a]
Σ SFA	30.7±2.26[a]	31±1.67[a]	31.82±2.78[a]
Σ MUFA	22.65±3.04[a]	21.67±5.31[a]	19.06±3.02[a]
Σ n-6 PUFA	12.44±2.77[ab]	13.01±0.77[a]	10.51±0.70[b]
Σ n-3 PUFA	34.21±3.09[b]	34.33±3.35[b]	38.61±3.64[a]
Σ n-3 HUFA	29.55±3.02[b]	32.45±3.70[ab]	36.46±4.08[a]
n-3/n-6	2.9±0.75[b]	2.65±0.24[b]	3.7±0.46[a]

SD – Standard Deviation; a, b – significant difference ($P \leq 0.05$). The same letter indicates the absence of significant differences between extensively-cultured and wild perch.
LA-linoleic acid (C18:2), AA-arachidonic acid (C20:4), ALA-α-linolenic acid (C18:3), EPA-eicosapentaenoic acid (C20:5), DPA-docosapentaenoic C22:5(n-3), DHA-docosahexaenoic (C22:6).
Σ SFA (saturated fatty acid) contains C12:0, C14:0, C15:0, C16:0, C17:0, C18:0 and C20:0.
Σ MUFA (monounsaturated fatty acid) contains C14:1, C16:1, C18:1, C20:1(n-7) and C20:1(n-9).
Σ n-6 PUFA (polyunsaturated fatty acid) contains C18:2, C18:3γ-lin, C20:2, C20:3, C20:4 and C22:5.
Σ n-3 PUFA (polyunsaturated fatty acid) contains C18:3, C18:4, C20:3, C20:4, C20:5 EPA, C22:5 and C22:6 DHA.
Σ n-3 HUFA (highly unsaturated fatty acid) contains C20:3, C20:4, C20:5 EPA, C22:5 and C22:6 DHA.

Table 3. Fatty acid contents (% of total fatty acids) in the liver lipids of the studied perch (mean±SD)

Fatty acid	Extensively-Cultured Perch		Wild Perch
	Pond (n = 8)	Lake Mosąg (n = 7)	Lake Wadąg (n = 6)
C18:2(n-6) LA	3.87±0.97[a]	3.68±1.19[a]	2.53±1.35[a]
C20:4(n-6) AA	8.65±1.98[a]	7.65±1.66[a]	8.61±2.16[a]
C18:3(n-3) ALA	2.23±0.85[a]	1.24±0.34[b]	0.98±0.39[b]
C20:5(n-3)EPA	5.55±1.44[a]	2.93±1.61[b]	5.95±1.98[a]
C22:5(n-3) DPA	1.6±0.52[a]	1.18±0.47[a]	1.15±0.61[a]
C22:6(n-3)DHA	23.05±3.45[ab]	18.12±4.91[b]	23.03±4.28[a]
Σ SFA	31.11±2.18[b]	36.01±4.05[a]	32.98±3.74[ab]
Σ MUFA	20.79±4.51[a]	25.64±5.43[a]	21.83±4.48[a]
Σ n-6 PUFA	14.37±2.88[a]	13.73±1.44[a]	12.87±3.36[a]
Σ n-3 PUFA	33.73±4.18[a]	24.62±6.58[b]	32.32±5.98[a]
Σ n-3 HUFA	31.09±4.18[a]	23.12±6.80[b]	31.12±5.85[a]
n-3/n-6	2.42±0.52[ab]	1.8±0.52[b]	2.51±0.76[a]

SD – Standard Deviation; a, b – significant difference ($P \leq 0.05$). The same letter indicates the absence of significant differences between extensively-cultured and wild perch.
LA-linoleic acid (C18:2), AA-arachidonic acid (C20:4), ALA-α-linolenic acid (C18:3), EPA-eicosapentaenoic acid (C20:5), DPA-docosapentaenoic C22:5(n-3), DHA-docosahexaenoic (C22:6).
Σ SFA (saturated fatty acid) contains C12:0, C14:0, C15:0, C16:0, C17:0, C18:0 and C20:0.
Σ MUFA (monounsaturated fatty acid) contains C14:1, C16:1, C18:1, C20:1(n-7) and C20:1(n-9).
Σ n-6 PUFA (polyunsaturated fatty acid) contains C18:2, C18:3γ-lin, C20:2, C20:3, C20:4 and C22:5.
Σ n-3 PUFA (polyunsaturated fatty acid) contains C18:3, C18:4, C20:3, C20:4, C20:5 EPA, C22:5 and C22:6 DHA.
Σ n-3 HUFA (highly unsaturated fatty acid) contains C20:3, C20:4, C20:5 EPA, C22:5 and C22:6 DHA.

had a significantly higher ratio of n-3/n-6 ($P \leq 0.05$). The ratio of n-3/n-6 did not differ significantly between liver of pond perch and perch from Lake Mosąg or liver of pond perch and perch from Lake Wadąg ($P > 0.05$).

Discussion

The fish muscles contained lower values of total lipid (0.49-0.61%) than liver (0.76-1.39%), but did not differences between the muscles of fish studied ($P > 0.05$). In the case of liver of fish examined observed thesame regularity ($P > 0.05$). According to Szczerbowski (1995), perch, which is one of the most popular species in latitude, is also a very tasty and prized freshwater fish. This fish is classified as a lean fish (below 2% lipid). This is in accordance with the results of Orban *et al*. (2007) who reported that fillets of perch (114.15-126.23 g) caught from the three different lakes in Italy, had low lipid levels (varying

Table 4. Fatty acids content (% of total fatty acids) in the muscles lipids of perch studied (mean±SD)

Fatty acid	Extensively-Cultured Perch		Wild Perch
	Pond (n = 8)	Lake Mosąg (n = 7)	Lake Wadąg (n = 6)
C12:0	0.25 ± 0.39[a]	0.1±0.01[a]	0.09±0.05[a]
C14:0	1.47±0.33[a]	1.43±0.24[a]	1.63±0.37[a]
C15:0	0.55±0.08[a]	0.48±0.07[a]	0.52±0.15[a]
C16:0	22.56±1.33[a]	22.6±1.01[a]	23.06±1.61[a]
C17:0	0.63±0.06[a]	0.54±0.04[b]	0.63±0.12[a]
C18:0	5.06±0.83[a]	5.71±0.68[a]	5.71±0.76[a]
C20:0	0.18±0.04[a]	0.14±0.02[b]	0.17±0.04[ab]
C14:1	0.09±0.04[a]	0.09±0.05[a]	0.08±0.03[a]
C16:1	6.29±1.69[a]	6.95±2.65[a]	5.99±1.65[a]
C18:1	15.4±2.12[a]	14.08±2.64[ab]	12.56±1.49[b]
C20:1(n-7)	0.24±0.36[a]	0.15±0.04[a]	0.1±0.02[a]
C20:1(n-9)	0.63±0.89[a]	0.39±0.06[a]	0.33±0.04[a]
C18:3γ-lin (n-6)	0.36±0.07[a]	0.39±0.22[a]	0.28±0.03[a]
C20:2 (n-6)	0.27±0.07[ab]	0.3±0.02[a]	0.23±0.03[b]
C20:3(n-6)	0.27±0.09[ab]	0.3±0.03[a]	0.21±0.03[b]
C22:5(n-6)	1.2±0.24[ab]	1.47±0.35[a]	1.1±0.13[b]
C18:4 (n-3)	0.83±0.40[a]	0.23±0.11[b]	0.38±0.14[b]
C20:3(n-3)	0.31±0.07[ab]	0.25±0.04[b]	0.33±0.06[a]
C20:4(n-3)	0.6±0.15[ab]	0.43±0.07[b]	0.8±0.29[a]

SD–Standard Deviation; a, b – significant difference (P≤0.05). The same letter indicates the absence of significant differences between extensively-cultured and wild perch.

Table 5. Fatty acids content (% of total fatty acids) in the liver lipids of perch studied (mean±SD)

Fatty Acid	Extensively-Cultured Perch	Wild Perch	
	Pond (n = 8)	Lake Mosąg (n = 7)	Lake Wadąg (n = 6)
C12:0	0.14±0.29[a]	0.03±0.01[a]	0.04±0.02[a]
C14:0	1.1±0.16[b]	1.72±0.42[a]	1.74±0.30[a]
C15:0	0.54±0.07[a]	0.38±0.09[b]	0.57±0.17[a]
C16:0	21.37±2.33[b]	25.22±3.53[a]	21.53±3.15[b]
C17:0	0.76±0.12[b]	0.59±0.21[b]	1.03±0.32[a]
C18:0	6.99±0.97[a]	7.96±1.36[a]	7.80±1.58[a]
C20:0	0.21±0.07[a]	0.11±0.04[b]	0.28±0.11[a]
C14:1	0.03±0.02[b]	0.12±0.09[a]	0.07±0.05[ab]
C16:1	6.05±2.66[a]	9.09±4.26[a]	7.07±2.76[a]
C18:1	14.17±1.93[a]	15.75±1.54[a]	13.81±2.09
C20:1(n-7)	0.12±0.02[b]	0.11±0.04[b]	0.20±0.05[a]
C20:1(n-9)	0.43±0.12[b]	0.58±0.11[a]	0.69±0.09[a]
C18:3γ-lin (n-6)	0.43±0.15[a]	0.41±0.03[a]	0.49±0.14[a]
C20:2 (n-6)	0.38±0.11[a]	0.32±0.06[a]	0.43±0.19[a]
C20:3(n-6)	0.24±0.10[b]	0.54±0.20[a]	0.20±0.04[b]
C22:5(n-6)	0.8±0.32[ab]	1.12±0.42[a]	0.6±0.12[b]
C18:4 (n-3)	0.42±0.20[a]	0.25±0.05[b]	0.22±0.12[b]
C20:3(n-3)	0.52±0.14[a]	0.55±0.59[a]	0.62±0.20[a]
C20:4(n-3)	0.37±0.13[a]	0.35±0.08[a]	0.38±0.15[a]

SD–Standard Deviation; a, b – significant difference (P≤0.05). The same letter indicates the absence of significant differences between extensively-cultured and wild perch.

from 0.6 to 1.2%). European perch appear similar to the yellow perch. According to Gonzalez *et al*. (2006), wild and farmed yellow perch (150 g each) are both low in fat , but have a significantly higher content of fat and n-3/n-6 ratio in fillets of farmed yellow perch (more so than wild perch) this could be attractive to consumers interested in low-fat food choices with potential health benefits. Jankowska *et al*. (2007) also observed that the values of fat (1.3%) in fillets from cultured European perch (119.4 g) were significantly higher than for the wild specimens (116.1 g) (0.3%) (P≤0.01). According to Kołakowska *et al*. (2003), the lipid content in fish depends on food availability. Mairesse *et al*. (2007) found that muscles of domesticated perch (90.8 g) had significantly lower lipid content (1.0%) than wild fish (76.2 g) (1.2%) (P<0.05). Blanchard *et al*. (2008) measured the effect of different diets on fat and fatty acids in Eurasian perch (98.7-106.6 g) and found that there were no differences in the fillet or liver lipid contents of these

fish with different dietary treatments (1.1% and 15.0%, respectively). Kołakowska *et al*. (2003) also noted that the main factors affecting the lipid content are internal factors such species, sex, physiological status (gonad maturity, condition, age) and seasons. Łuczyńska *et al*. (2008) noted differences in fat content between the different fish species. The authors observed that muscles of vendace (*Coregonus albula* L.) contained more total lipid (2.78%) than pike (*Esox lucius* L.) (0.56%), roach (*Rutilus rutilus* L.) (0.64%), burbot (*Lota lota* L.) (0.80%), perch (*Perca fluviatilis* L.) (0.89%) and bream (*Abramis brama* L.) (1.03%). Stepanowska *et al*. (2012) observed that perch caught in spring (156.86 g) characterized greater body weight, length and higher quantities of lipid in comparison with the perch caught in autumn (86.46 g). Stanek *et al*. (2009) found that muscles of male and female perch from Gopło Lake caught in autumn (mean 95.02 g) had higher content of fat than the perch caught in spring (mean 103.19 g) ($P<0.05$). This is not in accordance with the results of Stanek *et al*. (2008), because the muscles of perch caught in December and June in the Włocławski Reservoir contained similar values of fat. The muscles of studied perch had low content of total lipid than other freshwater fish reported by Łuczyńska *et al*. (2012). Blanchard *et al*. (2005) andŻarski *et al*. (2012) confirmed that the total fat content depend on physiological status as well as gonad maturity. Jankowska *et al*. (2010) did not find significant differences in saturated fatty acids SFA between reared and wild perch. The previous studies by Jankowska *et al*. (2004) on other fish species (catfish, *Silurus glanis* L.) are comparable with those of Jankowska *et al*. (2010). Łuczyńska *et al*. (2012) observed that the major fatty acid among the SFA group in muscles of other fish species was palmitic acid. The predominant fatty acids in all perch tissues were C16:0, C18:1(n-9) and C22:6n-3 (DHA), regardless of dietary treatments (Blanchard *et al*. 2008). There was a higher content of MUFA in muscles and liver of perch from intensive rearing (119.3 g) (37.94% and 38.12%, respectively) than wild perch (116.0 g) (29.20% and 27.89%, respectively) ($P\leq0.01$) (Jankowska *et al*., 2010). The muscle tissue of the wild pike-perch also had a significantly ($P\leq0.01$) lower MUFA than in pike-perch fed natural and artificial diets (Jankowska *et al*., 2003). However, the total content of MUFA in meat of catfish fed natural (reared in ponds) (1341.1 g) and artificial feed (1189.4 g) did not differ significantly ($P > 0.01$) (Jankowska *et al.,* 2004). Stanek *et al*. (2008) found that in both seasons (autumn and spring), the main MUFA in the muscles of perch was C18:1 (oleic acid). According to Jankowska *et al*. (2010) the content of oleic acid in muscles of wild and reared perch was 13.74% and 17.14%, respectively ($P\leq0.01$) and in liver 10.59% and 14.10%, respectively ($P\leq0.01$). The above authors obtained significant differences in the content of n-6 PUFA in both liver and muscles ($P\leq0.01$) of wild and reared perch studied by the same authors, but fish from intensive rearing had a lower content of these fatty acids. No differences between the amounts of n-6 PUFA in meat utility of wild and cultured zander were observed by Jankowska *et al*. (2003). Significant differences in the content of n-6 PUFA were found in the liver of Eurasian perch fed diets containing different LnA/LA ratios ($P<0.05$) (Blanchard *et al*., 2008). The meat of catfish from a pond culture had significantly more n-6 PUFA than fish from intensive culture (Jankowska *et al*., 2004). For extensively- and intensively-farmed Eurasian perch, contrary regularity ($P<0.05$) (Stejskal *et al*., 2011) was also noted. Gonzalez *et al*. (2006) reported that not only diet, but also environmental conditions influenced different quality properties in both wild and farmed yellow perch. According to Stanek *et al*. (2008), n-6 PUFA was higher in the muscles of perch caught in autumn (12.71%) than those caught in spring (9.91%). Kołakowska *et al*. (2003) noted that freshwater fish contain higher proportions of n-6 PUFA and lower n-3 PUFA, allowed differentiation between freshwater and marine species. According to Steffens (1997), compared with marine fish, the freshwater fish were characterized by high levels of AA and LA as well as low levels of EPA and DHA. The same authors also noted, that freshwater fish such as salmonids and common carp fed on diets containing high amounts of fish oil resulted in marketable fish with substantial levels of n-3 PUFA. The literature showed that perch fed on different diets had more EPA and DHA in muscles than AA and LA (Xu and Kestemont, 2002). They also consistently had more n-3 PUFA than n-6 PUFA (Orban *et al*., 2007, Blanchard *et al*., 2005, Blanchard *et al*., 2008, Łuczyńska *et al*., 2008, Jankowska *et al*., 2010, Hossain *et al*., 2011). Stejskal *et al*. (2011) observed that perch had higher contents of n-3 PUFA than n-6 PUFA and DHA was predominant among n-3 PUFA. For catfish, the dominant fatty acids among n-3 PUFA were DHA and EPA (Jankowska *et al*., 2004). According to Łuczyńska *et al*. (2008), AA (6.55%), DHA (17.77%) and EPA (6.06%) acids were the predominant PUFA group in perch muscles. For DHA and EPA, the most valuable to consumers, in muscles of perch, there were no differences observed between the two groups (reared and wild fish) ($P>0.01$) (Jankowska *et al.,* 2010). However, there were no differences in the content of EPA in liver, in contrast to AA and DHA ($P\leq0.01$). The same authors also found the differences in the n-3/n-6 ratio in muscles and livers of the two groups examined ($P\leq0.01$) because liver and muscles in the reared fish had a higher ratio of n-3/n-6 than wild fish. Stejskal *et al*. (2011) observed that the ratio of n-3/n-6 PUFA was 1.42 for intensively-cultured perch (141.5 g) and 2.85 for the extensively-cultured group (147.6 g). Jankowska *et al*. (2010) did not observe differences ($P>0.01$) in the content of n-3 PUFA in muscles of reared and wild perch (27.13%

and 29.18%, respectively). Similarly, no significant differences were observed in the content of n-3 PUFA between wild and farmed yellow perch (Gonzalez *et al*., 2006). Xu and Kestemont (2002) noted that although Eurasian perch contains relatively low fat in muscles, it is a potential nutritional food fish for human consumption as it has a high content of DHA. The results of the above authors indicate that the high tissue DHA content in the muscles of Eurasian perch was attributable to the greater ability for n-3 acid bioconversion. Jankowska *et al*. (2010) suggested that perch displayed a capability for bioconversion of long-chain highly-unsaturated fatty acids (HUFA), especially of DHA, from their dietary precursors. Stejskal *et al.* (2011) observed that the values of n-3 PUFA were lower in intensively-farmed perch than in extensively-cultured perch. On the other hand, fillets of intensively-cultured perch may be a good source of LA, EPA, and DHA, whereas fillets of extensively-cultured perch may be considered sources of ALA, EPA, and DHA. This present study provides information on essential fatty acids, which have potential beneficial human health effects similar like other species, for instance rainbow trout (*Oncorhynchus mykiss* Walb.) (Celik *et al*., 2008, Taşbozan *et al*., 2016). Therefore, it can be stated that meat of perch is good sources of fatty acids, both from the point of view of processing fish and human diet.

Conclusions

Perch (*Perca fluviatilis* L.) living in lakes are better sources of DHA than perch reared in polyculture with carp and fed natural food (roach, perch). These results indicate less diversified feed in the case of extensively-cultured perch, although this perch had more DHA than other fish of this species studied by some authors (e.g. from natural aquifers and from intensive rearing in a closed circuit on an artificial feed mixture or reared in an extensive pond-based system in a polyculture with carp and tench). This is why perch from pond culture fed on natural food can also be considered as a good source of DHA. On the other hand, no difference was found in EPA between muscles of the examined groups, and in n-3 PUFA, n-3 HUFA or n-3/n-6 ratio between muscles of perch from a pond culture and living under natural conditions. Furthermore, the fish of the two examined groups had a higher content of n-3 PUFA than n-6 PUFA and low fat levels and may be an important dietetic fish food from a consumer health point of view.

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