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Short communications

IMPACT OF DIFFERENT FISHING SEASONS ON THE FATTY ACIDS PROFILE, CHOLESTEROL CONTENT, AND FAT IN THE MUSCLES OF PERCH, *PERCA FLUVIATILS* L. FROM THE WŁOCŁAWSKI RESERVOIR (CENTRAL POLAND)

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ABSTRACT. The aim of the study was to compare the fatty acids profile, fat content, and total cholesterol in the muscles of female perch, *Perca fluviatilis* L., caught in fall and spring. The group of fish examined was comprised of perch caught in the Włocławski Reservoir in December 2005 and June 2006. Analysis indicated that the muscles of the fish caught in fall had higher total cholesterol and fat content (53.91 mg 100 g^{-1} and 2.17%, respectively) in comparison with the level of these parameters in the muscles of perch caught in spring (44.74 mg 100 g^{-1} and 1.94%, respectively). In both seasons, the main saturated fatty acid (SFA) was C16:0, the monounsaturated fatty acids (MUFA) were dominated by C18:1 n-6, and the highest percentage of polyunsaturated fatty acids (PUFA) was of C20:5 n-3. The total SFA and PUFA was higher in the muscles of perch caught in fall at 47.53 and 28.65%, respectively, in contrast to the values of these acids in spring, which were 43.02% and 21.73%, respectively. Total MUFA in fall (23.83%) was lower than in spring (32.24%).

Key words: FATTY ACIDS, FAT, CHOLESTEROL, PERCH

Fatty acids play key roles in many biochemical processes that occur in organisms. The essential fatty acids (EFA) required for the proper functioning of organisms include polyunsaturated fatty acids (PUFA) containing 18-carbon chains and highly unsaturated fatty acids (HUFA) that have 20 and 22 carbon atoms and belong to the n-3 and n-6 families. These acids are not synthesized by the human body nor by the bodies of

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most animals (Smith et al. 2004). The appropriate proportion of n-3 and n-6 acids in the diet is crucial for the proper functioning of human and animal bodies. Acids from the n-3 family lower serum levels of triglycerols and LDL. Long-chain acids from the n-3 family impede caners, skin disease, and asthma (Steffens and Wirth 2005). PUFA from the n-6 family are key for the synthesis of prostaglandins, prostacyclin, and the formation of cell membranes. Arachidonic acid (C20:4 n-6) is essential for fish reproduction as it participates in gonadal steroidogenesis. While there is a lot of information regarding the content of fat and fatty acids in the muscles of marine fish in the scientific literature, there is decidedly far less data available on this topic regarding freshwater fish (Bieniarz and Kołdras 2000).

The fat, cholesterol, and fatty acids levels in animal tissues are determined by a variety of factors including environmental conditions, physiological state, food type, sex, and age (Luzzana et. al 1996). The aim of the study was to determine the fatty acids profiles, percentage content of fat, and levels of total cholesterol in the muscles of perch, *Perca fluviatilis* L., caught in the Włocławski Reservoir in fall, after the intense feeding period, and in spring, after spawning.

The Włocławski Reservoir was created in 1970 when the Vistula River was damed at its 675 km, and remains today the largest water body of its type in Poland. The surface area of the reservoir is about 75 km^2, its length is 57 km, and its width ranges from 500 to 2500 m (mean 1210 m). The average depth is 5.5 m and the maximum is 15 m (Archem and Gierszewski 2007). More than thirty species of fish occur in the Włocławski Reservoir. In the 2002-2006 period, bream, *Abramis brama* (L.), dominated the catches, while perch comprised from 5.2 to 8.7% of the biomass of commercial catches and was the dominant among piscivorous species.

The study focused on two groups of perch females caught in the lower part of the Włocławski Reservoir in fall (December 2005) and spring (June 2006). A total of 34 specimens were collected, 17 individuals in each season. After they were caught, length and body weight measurements were recorded for each specimen to the nearest 1 mm and 0.01 g, respectively. The body length of the fish caught in fall ranged from 16.0 to 18.5 cm (mean 17.1 cm), and body weight was from 83.9 to 113.4 g (mean 95.02 g), while the corresponding measurements of the fish caught in spring were 17.0 to 19.5 cm (mean 18.0 cm) and 85.9 to 122.5 g (mean 103.19 g). The muscle samples for analysis were from the large side muscle of the perch body above the lateral line. The mus-

cle samples (about 12 g), including the skin, were freeze dried, and then the fatty acids composition (% of the determined fatty acids), fat contents (%), and the total cholesterol concentration (mg 100 g^{-1}) were determined. The analyzed muscle samples were freeze dried in a Lyovac GT2 freeze-drier by Finn-Aqua (Finland).

The fatty acids profile was determined with a 3800GC gas chromatograph and a flame-ionization detector (Varian, USA). The temperature of the injector was 230°C, and that of the detector was 250°C. The volume of the injected sample was 1 μl (split 1:50). A Supelcowax 10 column was used in the analysis. The carrier gas was helium at a flow rate of 1.5 cm^3 min^{-1}. Analysis was performed at a program temperature range of 90 to 250°C (11°C min^{-1}), 225°C for 6 min, and then an increase from 225 to 240°C (6°C min^{-1}) and 240°C for 19 min. After fat extraction with the method by Folch et al. (1957), methylization was performed with a solution of sodium methanol (0.5 mol dm^{-3}) for 22 hours at a temperature of 37°C. Isooctan was added to extract methyl esters from the fatty acids. The group of analyzed fatty acids included saturated acids (C14, C15, C16, C17, C18, C24), monoenoic fatty acids (C14:1 n-5, C15:1 n-6, C16:1 n-7, C17:1 n-8, C18:1 n-9, C18:1 n-7) and polyenoic fatty acids (C16:2 n-4, C18:2 n-6, C18:3 n-3, C20:4 n-6, C20:5 n-3, C22:6 n-3). The methyl esters of the fatty acids were identified with a Supelco PUFA-2 Animal Source and a Supelco 37 component FAME Mix (Supelco, USA). Cholesterol was determined with the modified Liebermann-Burchardt colorimetric method (Strzeżek and Wołos 1997) using a Shimadzu (Japan) spectrophotometer. Cholesterol was extracted from samples of 0.25 g of freeze-dried tissue with 15 cm^3 of chloroform. After filtration, the solution was supplemented with chloroform in the measurement container to a volume of 25 cm^3. One cm^3 of acetic anhydride and 0.25 cm^3 of sulfuric acid (VI) were added to 2 cm^3 of the filtrate obtained. After 5 min the absorption value was measured in a blind test at a wavelength of 620 nm. The results are presented as mg 100 g^{-1} of wet weight. The percentage content of fat in the dorsal muscles was determined with the modified method by Folch et al. (1957). Fat was extracted from freeze-dried tissue (2 g) with 30 cm^3 of a mixture comprised of chloroform and methanol (2:1). Significant differences in the mean values of the individual fatty acids, total cholesterol, and fat in the muscles of the perch caught in fall and spring were tested with the t test at a degree of significance of $P < 0.05$.

Of the group of SFA analyzed, the highest percentage was of C16:0 in the muscles of perch caught both in fall (33.31%) and spring (31.53%) (Table 1). In both groups the lowest percentage of fatty acids was of C15:0. The mean percentage of the content of fatty acids C14, C16, C17, and C24 in the muscles differed statistically significantly between the perch caught in fall and spring. Of the MUFA group, the highest percentage was of C18:1 n-9 in the muscles of both the fish caught in fall (11.08%) and spring (15.55%) (Table 1). The lowest amount of this group was of C14:1 in fall, while in spring the lowest amounts were of C14:1 and C15:1 at similar levels. The mean percentage content of acids C14:1, C15:1, C16:1, and C18:1 n-9 differed statistically significantly between the catch seasons (t test, $P < 0.05$). The analysis of PUFA indicated that the highest percentage share was of C20:5. The fish caught in fall contained 8.28% of this fat, while the muscles of fish caught in spring contained 6.17% (Table 1). The lowest share of PUFA was of C18:3 in the muscles of perch caught in fall and of C16:2 in fish caught in spring. Statistical analysis indicated there was a statistically significant difference in the mean percentage contents of all PUFA with the exception of C18:2. The mean value of SFA in the muscles of the fish was about 30% of all the acids determined (Luzzana et al. 1996, Jankowska et al. 2003). The value of this in the perch from the Włocławski Reservoir exceeded 40%. The studies by Luzzana et al. (1996) indicated that the SFA content in the muscles of female *Coregonus macrophthalmus* Nüsslin from Lake Maggiore (northern Italy) were higher in the growth season in September than they were in the spawning season in January (respectively 28.7 and 24.5%, of the fatty acids determined). This is due to the female's use of SFA as the main source of energy during spawning. In both of the studied seasons, the highest percentage share of the SFA was of C16:0. Jankowska et al. (2003) reported that in the muscles of 17-month-old pikeperch, *Sander lucioperca* (L.), caught in mid November in Lake Tałty-Ryńskie (northern Poland), SFA comprised 27.84% of the acids determined, among which C16:0 occurred in the largest amount (19.91%).

Studies of salmon from Lake Maggiore indicated that the total MUFA was higher in the spawning season (36.7%) than in the growth season (30.2-31.6%) (Luzzana et al. 1996). In their own research, the authors of the current paper obtained similar results, namely that total MUFA in the muscles of perch caught in the fall comprised 23.83% of the determined acids, while in spring 32.24%.

TABLE 1

Fatty acids content (% of the determined acid; mean±SD) in the muscles of perch caught in December and June in the Włocławski Reservoir

Fatty acids	Catch period		*P*
	December (n=17)	June (n=17)	
SFA			
C14 (Myristic acid)	1.03 ± 0.14	2.59 ± 0.54	0.0000
C15 (Pentadecanoic acid)	0.59 ± 0.08	0.58 ± 0.13	0.8305
C16 (Palmitic acid)	33.31 ± 2.52	31.53 ± 1.69	0.0242
C17 (Heptadecanoic acid)	0.90 ± 0.09	0.66 ± 0.15	0.0000
C18 (Stearic acid)	7.14 ± 0.70	6.96 ± 1.45	0.6592
C24 (Lignoceric acid)	4.56 ± 0.50	3.70 ± 0.98	0.0030
Σ SFA	47.53 ± 2.36	46.02 ± 2.80	0.1004
MUFA			
C14:1 (Myristoleic acid)	0.22 ± 0.03	0.33 ± 0.08	0.0001
C15:1 (cis-10-pentadecanoic acid)	0.37 ± 0.07	0.31 ± 0.08	0.0211
C16:1 (Palmitoleic acid)	6.82 ± 1.08	10.93 ± 3.20	0.0000
C17:1 (cis-10-heptadecanoic acid)	0.92 ± 0.10	0.90 ± 0.15	0.6781
C18:1 (Oleic acid)	11.08 ± 1.13	15.55 ± 2.32	0.0000
C18:1 (trans-11-octadecanoic acid)	4.42 ± 0.41	4.22 ± 0.44	0.1706
Σ MUFA	23.83 ± 2.02	32.24 ± 5.39	0.0000
PUFA			
C16:2 (Hexadecadienoic acid)	2.21 ± 0.52	1.44 ± 0.50	0.0001
C18:2 (Linoleic acid)	4.77 ± 1.61	5.64 ± 0.90	0.0587
C18:3 (α-linolenic acid)	1.28 ± 0.23	1.57 ± 0.22	0.0006
C20:4 (Arachidonic acid)	7.95 ± 1.18	4.26 ± 1.34	0.0000
C20:5 (Eicosapentaenoic acid)	8.28 ± 1.06	6.17 ± 1.19	0.0000
C22:6 (Docosahexaenoic acid)	4.15 ± 0.99	2.65 ± 0.86	0.0000
Σ PUFA	28.65 ± 2.97	21.73 ± 3.12	0.0000
Σ n-3	13.72 ± 1.64	10.39 ± 1.85	0.0000
Σ n-6	12.71 ± 1.75	9.91 ± 1.90	0.0000

The lower amounts of PUFA in the muscles of fish caught during the spawning season results from the decomposition of some polyunsaturated fatty acids, especially C20:5, during spawning. Phospholipids comprise two-thirds of the structure of ovaries and are the main source of energy for growing oocytes. The authors' own research indicated that the content of C20:4, C20:5, and C22:6 in the muscles of fish caught in fall was higher than that in the muscles of fish caught in spring and that these differences were statistically significant. The highest percentage among PUFA was of C20:5

(8.28% in the muscles of perch caught in fall and 6.17% in the muscles of perch caught in spring). The mean value of C20:5 determined in fall was similar to that value of this same fatty acid in the meat of pikeperch from the Oder and Regalica rivers and pikeperch from Lake Tałty-Ryńskie at 8.78 and 7.49%, respectively (Kołakowska et al. 2000, Jankowska et al. 2003). Jankowska et al. (2003) reported that among PUFA, C22:6 occurred in the highest amount (24.50%).

The ratio of n-3 PUFA/n-6 PUFA was 0.57 for perch caught in fall and 0.62 for specimens caught in spring. The n-3/n-6 ratio in the muscles of freshwater fish ranged from 0.5 to 3.8. Research indicates that freshwater fish usually have higher contents of n-6 PUFA (C18:2, C20:4) in comparison to marine fish that are rich in n-3 MUFA (C20:5 and C22:6). However, many freshwater fish (carp, *Cyprinus carpio* L. European catfish, *Silurus glanis* L., vendace, *Coregonus albula* (L.), tench, *Tinca tinc*a (L.)) that feed on natural food are richer in the n-3 family of acids and that the value of the n-3/n-6 coefficient depends on the type of diet consumed (Steffens and Wirth 2005).

The perch caught in fall had higher total cholesterol contents in comparison with the fish caught in spring (Table 2). The mean value of total cholesterol in the meat of perch caught in fall and spring was 53.91 and 44.74 mg 100 g^{-1}, respectively, and the differences between these means were statistically significant (t test, $P < 0.05$). The mean fat content determined in the muscles of fish caught in fall (2.17%) was slightly higher in comparison to the fish caught in spring (1.94%) (Table 2; t test, $P > 0.05$).

TABLE 2

Content of cholesterol (mg 100 g^{-1} wet weight) and fat (%) in muscles of perch from Włocławskie Reservoir

Parameter	Season	Mean ± SD	Range (n = 17)
Cholesterol	Fall	53.91 ± 6.45^{a}	43.00-62.46
	Spring	44.74 ± 5.94^{b}	33.34-53.40
Fat	Fall	2.17 ± 0.54^{a}	1.360-3.201
	Spring	1.97 ± 0.58^{a}	1.064-3.001

Values in the same parameter with different letter index differ significantly statistically (t test, P < 0.05)

Konarzewski et al. (1968) reported that the fat content of perch muscle ranged from 0.7 to 4.6%. The mean total cholesterol content in the muscles of perch caught in fall in the Włocławski Reservoir was 53.91 mg 100g^{-1}, which was close to the results for carp obtained in October, which had a mean concentration of 53.80 mg 100 g^{-1} (Bieniarz et al. 2001).

CONCLUSIONS

1. PUFA, such as C16:2, C20:4, C20:5, and C22:4 occurred in greater quantities in the muscles of perch caught in fall than in those caught in spring.
2. The mean percentage content of MUFA in the meat of perch caught in fall was lower than in fish caught in spring.
3. The mean SFA content was similar in the fish caught in both seasons.
4. Fish caught in fall had higher contents of total cholesterol and fat in comparison with the perch caught in spring.

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STRESZCZENIE

WPŁYW RÓŻNYCH SEZONÓW ODŁOWU NA PROFIL KWASÓW TŁUSZCZOWYCH, ZAWARTOŚĆ CHOLESTEROLU ORAZ TŁUSZCZU W MIĘSIE OKONIA (*PERCA FLUVIATILS* L.) ZE ZBIORNIKA WŁOCŁAWSKIEGO (CENTRALNA POLSKA)

Celem badań było porównanie profilu kwasów tłuszczowych, zawartości tłuszczu i cholesterolu całkowitego w mięsie samic okoni, *Perca fluviatilis* L. pomiędzy wiosną i jesienią. Grupę badawczą stanowiły okonie ze Zbiornika Włocławskiego pozyskane w grudniu 2005 roku i czerwcu 2006 roku. Analiza wykazała, że w mięsie ryb odłowionych jesienią było większe stężenie cholesterolu całkowitego (53,91 mg 100 g^{-1}) i tłuszczu (2,17%), w porównaniu z poziomem tych parametrów w mięsie okoni pozyskanych wiosną, kiedy zawartość cholesterolu całkowitego wynosiła 44,74 mg 100 g^{-1}, a tłuszcz stanowił 1,94%. W obu sezonach głównym kwasem spośród nasyconych kwasów tłuszczowych (SFA) był C16:0, w grupie monoenowych kwasów tłuszczowych (MUFA) dominował C18:1 n-6, a spośród polienowych kwasów (PUFA) największy procent stanowił C20:5 n-3. Suma SFA i PUFA była wyższa w mięsie okoni pozyskanych jesienią i stanowiła odpowiednio 47,53 i 28,65%, w przeciwieństwie do wartości tych kwasów u ryb odłowionych wiosną, u których SFA stanowiło 43,02%, a PUFA 21,73%. Suma MUFA jesienią (23,83%) była niższa niż wiosną (32,24%).