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FATTY ACID PROFILES AND FAT CONTENTS OF COMMERCIALLY IMPORTANT FISH FROM VISTULA LAGOON

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Investigations were conducted for fat content and fatty acids composition of six of the most frequently fished species inhabiting the Vistula Lagoon (bream, roach, perch, pikeperch, herring, and eel). Fat content of the fish examined ranged from 0.39 to 29.77%, whereas fatty acids composition range was as follows: saturated fatty acids (SFA) 25.1–29.4%, monounsaturated fatty acids (MUFA) 22.3–52.2%, and polyunsaturated fatty acids(PUFA) 18.5–52.2%. Among the SFAs, palmitic acid dominated (C16:0). Oleic acid (C18:1) had the greatest share of the MUFAs. PUFAs had a high share of acids from the n-3 family, especially of eicosapentaenoic (EPA) and docosahexaenoic (DHA) acids. A high share of these acids was confirmed in the fats of pikeperch (33.25%) and perch (31.02%). The total contents of EPA and DHA in 100 g of muscle tissue of the fish examined in the current study was as follows: eel – 2.11 g; herring – 0.62 g; bream – 0.33 g; roach – 0.19 g; perch – 0.16 g; and pikeperch – 0.14 g (the recommended daily dose for healthy persons is 0.5 g). At the recommended minimum value of 0.45, the ratios of n-6/n-3 (0.18 – 0.55) and PUFA/SFA (0.63 – 2.04) were advantageous in the fats of the fish examined.

INTRODUCTION

The Vistula Lagoon is a brackish water basin in the southern Baltic Sea. The area of the basin is 838 km^2, and its Polish part constitutes 328 km^2 with a maximum depth of 4.4 m. The lagoon has a specific hydrological system that is shaped by inputs of inland fresh water and saline waters from the Gulf of Gdansk [Psuty-Lipska & Draganik, 2005]. There are 16 commercially significant species occurring in the lagoon, including freshwater (bream, pikeperch, roach, perch, sichel, smelts, ruffe, burbot, vimba bream, white bream, asp, wels), anadromous (eel, sea trout), and marine (herring, flounder) fish. The dominant species in the catches are herring, pikeperch, bream, eel, roach, and perch. Pikeperch have the highest frequency of occurrence in the catches, while bream, eel, perch, and roach are less frequent. Large numbers of herring are only caught in fyke-nets during the spawning season in the spring (March to May) and in lower numbers in the fall (October to November) [Psuty-Lipska, 2006].

Many sources emphasize that marine fish have a higher nutritive value than do freshwater fish [Özogul & Özogul, 2007; Özogul *et al*., 2007a, Ackman *et al.,* 2002]. The nutritive value of fish comes mainly from the easily-digestible protein and fat it contains. Fish fats are characterized by an advantageous composition of fatty acids with a large percentage of unsaturated essential fatty acids (LC-PUFA), including eicosapentaenoic (EPA) and docosahexaenoic (DHA) acids. These acids may be synthesized by animals or humans only to a limited extent and must be supplemented by the diet [Steffens, 1997]. These fatty acids from the n-3 family occur in fish in large amounts. This is why both consumers and scientists alike are interested in conditions such as asthma, arteriosclerosis, and joint inflammation as well as delaying the development of cancers [Kinsella, 1988]. In order to prevent cardiovascular disease, the ratio of PUFE/SFA consumed should be less than 0.45 [HMSO, 1994]. Fish lipids are known to have high quantities of acids from the n-3 family, the most important of which are EPA and DHA. These acids play the most important role in the prevention of cardiovascular diseases. The daily prophylactic dose of DHA and EPA for children is 0.5 g while for adults and patients with circulatory disorders it is 1-4 g [Kris-Etherton *et al*., 2002]. Fish oils also contain polyunsaturated acids from the n-6 family, which have an antagonistic effect on n-3 acids. This is why the ratio of n-6/n-3 acids is so important. The UK Department of Health recommends a maximum n-6/n-3 ratio of 4.0 [HMSO, 1994]. Generally, it is clear that there are many parameters in fish oils that have a positive impact on the health of consumers.

While the health benefits gained by including marine or farmed fish in the diet are largely known, the nutritive values of fish from the Vistula Lagoon are, as yet, undetermined. The consumption of fish in Poland is small and the population should thus be encouraged to change habits. Therefore, the present paper reports the lipid content and fatty acid compositions of commercial fish species form Vistula Lagoon.

The aim of this study was to demonstrate that fish from Vistula Lagoon are characterized by a high nutritive value resulting in a significant quantity of essential unsaturated fatty

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acids, especially DHA, a profitable ratio of fatty acids from n-6 and n-3 families, and with a proper PUFA/SFA ratio.

MATERIAL AND METHODS

Fish

The subject of the studies were six species of fish that occurred most frequently in the Vistula Lagoon in 2007, namely: eel (*Anguilla anguilla* L.), herring (*Clupea harengus* L.), bream (*Aramis brama* L.), pikeperch (*Stizostedion lucioperca* L.), roach (*Rutilus rutilus* L.), and perch (*Perca fluviatilis* L.). The fish samples were collected from catches in spring (March-June), (Table 1).

Sample preparation

The fish were transported to the laboratory on ice, or, if analysis was not possible the same day, the fish were stored at a temperature of 0°C for two to three days. Muscle tissue for analysis was collected from 4 to 40 individuals, depending on individual fish size. The length of the fish species studied was as follows: eel – 50-85 cm, herring – 18-28 cm, bream – 35-53 cm, pikeperch – 30-56 cm, roach – 18-31 cm, and perch – 18-30 cm. The tissue samples were homogenised, frozen, and hydrolysed.

Fat extraction

A Soxtec Avanti 2050 device was used to extract the fats. The cartridges were filled with 20 g of hydrolysed fish tissues and were placed in the extraction setup. The extraction process was conducted with hexane/acetone (80 ml, 4:1 v/v) according to the following procedure: bath temperature -125°C; heat extraction (1.5 h); cold extraction (2.5 h). Hexane/acetone was evaporated from the oil obtained on an evaporator and then in a stream of neutral gas.

Fatty acid methylation

Fatty acid metal esters were prepared according to the following procedure: approximately 0.05 g of oil was measured into a 5 mL reaction dish to which 0.8 mL of a 2 mol/L solution of potassium hydroxide in methanol was added. The solution was heated for 15 min in a heating block at a temperature of 78±4°C. Next, it was cooled to a room temperature and then 1.6 mL of a 4% solution of hydrochloric acid in methanol was added. The sample was reheated in the heating block at 78±4°C for 15 min. After cooling to a room temperature, 0.8 mL of isooctane was added. The solution was mixed and supplemented to a volume of 5 mL with a saturated solution of sodium chloride and a pinch of dehydrated sodium sulfate to dry out the layer of isooctane. The isooctane extract was placed in an Agilent 6890N (Varian) gas chromatograph autosampler.

Gas chromatographic conditions

The fatty acid composition was analysed with an Agilent 6890N GC equipped with a flame ionization detector (FID) and a capillary column (100 m x 0.25 mm, 0.20-μm film thickness SP-2560 phase). The oven temperature was 100°C and was held for 5 min, then raised to 240°C at a rate of 4°C /min and then held for 17 min. The injector temperature was set at 250°C. The sample size was 0.2 μL and the carrier gas was helium. The split used was 1:100. The fatty acids were identified by comparing the retention times of FAME with the standard 34 component FAME mixture (Accustandard).

Quality control/assurance

The SFI's laboratory has been accredited for analysis since 1994 (Accreditation certificate no. AB 017) and annually participates with satisfying results in the intercalibration trials organized by FAPAS. Results z-score for Vegetable oil Test Material, March-April 2006: saturates – Z = 0.8, monounsaturates – Z = 0.0, polyunsaturates – Z= -0.3.

Quality assurance of each series of analysis (10 samples) was secured through a parallel analysis of one sample of each series in three replicates.

The PUFA content (EPA and DHA) in g per 100 g of fish fillets was calculated according to Méndez *et al*. [1996] and Vasilopoulou *et al*. [2003] using conversion factors of 0.956 and the total lipid content of fish.

RESULTS AND DISCUSSION

Depending on their fat content, fish are classified as lean (up to 2% fat), medium fat (2-7% fat), fat (7-15% fat), and very fat (over 15% fat) [Polish Standard PN-A-86770, 1999]. According to the classification provided by the Polish Standard [PN-A-86770, 1999], the roach, perch, and pikeperch examined were lean fish. The fat content in the meat of the fish examined was 0.79% in roach, 0.46% in perch, and 0.39% in pikeperch (Table 1). Herring and bream contained 2.6 and 3.14% fat, respectively, and were thus medium-fat fish, while eel were very fat with fat contents of 29.77%. The quantity of fat in fish depends, among other factors, on the developmental stage of the individual, the geographical region of its occurrence, its diet, and the season of the year [Rasoarahona *et al*., 2005; Gökçe *et al*., 2004]. The fish examined in the current study were caught in the spring (March-June). The fat content of herring measuring from 18 to 28 cm in length ranged from 1.98 to 3.38%, respectively, and in bream measuring from 35 to 53 cm it ranged from 2.11 to 4.05%. Pikeperch from 30 to 56 cm in length contained from 0.34 to 0.42% fat, and eel measuring from 50 to 85 cm had a fat content range of 24.7 to 35.06%. The values of fat content of freshwater fish

TABLE 1. Data of investigated fish from the Vistula Lagoon.

Species	Number of samples	Range of lengths (cm)	Lipid (%) ± sd min-max
Eel (*Anguilla anguilla* L.)	10	50 – 85	29.77±3.47 24.70-35.06
Bream (*Aramis brama* L.)	11	35 – 53	3.14±0.78 2.11-4.05
Herring (*Clupea harengus* L.)	12	18 – 28	2.61±0.57 1.98-3.38
Roach (*Rutilus rutilus* L.)	10	18 – 31	0.79±0.20 0.51-1.01
Perch (*Perca fluviatilis* L.)	10	18 – 30	0.46±0.04 0.40-0.51
Pike perch (*Stizostedion lucioperca* L.)	10	30 – 56	0.39±0.04 0.34-0.42

sd – standard deviation

caught in the spring reported in the literature were similar. Bream from Lake Maróz in northern Poland contained 3.63% of fat [Żmijewski *et al*., 2006], pikeperch from the Turkish Lake Beysehir had 0.62% of fat [Guler *et al*., 2007], perch from the Szczecin Lagoon had 0.45% of fat [Falandysz *et al*., 2004], while that from the Great Lakes area of the United States contained 0.26% of fat [González *et al*., 2006].

The nutritive value of fish is determined by the content of fatty acids that are beneficial to health. Table 2 presents the composition of 34 fatty acids in the fish examined in the present study. The total fatty acids of the fish from the Vistula Lagoon were comprised of 25.1-29.4% of SFAs, 22.3-52.2% of MUFAs, and 18.5-52.2% of PUFAs (Table 3). The dominant SFA was palmitic acid (C16:0) constituting 16.0-19.9% of the total fatty acids and over 60% of the total SFAs. This fatty acids occurs in similar quantities (approximately 60% SFA) in freshwater fish from Turkish lakes (roach, pikeperch, carp) [Õzogul *et al*., 2007]. Palmitic acid is also the major SFA in the lipids of many marine fish species (perch, sardine, anchovy, picarel) constituting about 70% of the total SFAs [Krajnovic-Ozretic *et al*., 1994; Zlatanos & Laskaridis, 2007; Õzogul *et al*., 2007a]. Medium-fat and fat fish from the Vistula Lagoon (bream, herring, eel) have high quantities of MUFAs, which are predominated by oleic acid (C18:1n9c). This acid accounts for 12.3 to 40.5% of total fatty acids and for over 70% of the MUFAs. Oleic acid is the predominant among the MUFAs in the lipids of many species of freshwater and marine fish accounting for 60 to 75% of the MUFAs [Żmijewski *et al*., 2006; Méndez *et al*., 1996; Haliloglu *et al*., 2004; Õzogul *et al*., 2007a; Alasalvar *et al*., 2002]. The fats

TABLE 2. Fatty acid composition of fish from the Vistula Lagoon (% of total fatty acids detected ± sd).

Fatty acid	Eel	Bream	Herring	Roach	Perch	Pike perch
C12:0	0.13±0.03	0.04±0.02	0.06±0.02	0.04±0.01	0.02±0.02	0.01±0.01
C13:0	0.02±0.01	0.02±0.01	0.02±0.00	0.00±0.01	0.00±0.00	0.00±0.00
C14:0	4.03±0.26	2.46±0.22	6.56±0.81	2.15±0.20	1.58±0.21	1.55±0.37
C15:0	0.32±0.05	0.42±0.05	0.36±0.05	0.53±0.04	0.32±0.03	0.32±0.03
C16:0	19.82±0.46	18.93±0.82	19.88±0.94	16.95±1.25	17.97±2.00	16.00±0.46
C17:0	0.43±0.04	0.58±0.04	0.25±0.07	0.71±0.10	0.64±0.14	0.59±0.10
C18:0	4.28±0.16	3.62±0.29	1.97±0.24	4.29±0.48	5.23±0.97	6.02±2.18
C20:0	0.16±0.02	0.23±0.02	0.11±0.02	0.18±0.01	0.19±0.06	0.22±0.05
C21:0	0.04±0.01	0.06±0.03	0.03±0.01	0.07±0.01	0.03±0.02	0.04±0.03
C22:0	0.04±0.01	0.05±0.04	0.08±0.01	0.06±0.02	0.06±0.03	0.06±0.04
C23:0	0.04±0.01	0.08±0.02	0.08±0.01	0.09±0.02	0.34±0.13	0.35±0.24
C24:0	0.01±0.00	0.02±0.01	0.05±0.01	0.02±0.01	0.08±0.05	0.11±0.07
C14:1	0.21±0.02	0.19±0.01	0.06±0.02	0.14±0.05	0.13±0.07	0.07±0.04
C15:1	0.01±0.00	0.01±0.01	0.01±0.00	0.02±0.03	0.01±0.01	0.05±0.06
C16:1n7	9.69±0.78	13.18±0.56	5.57±1.09	11.07±1.32	8.41±1.10	6.76±0.88
C17:1n7	0.07±0.01	0.21±0.06	0.06±0.01	0.48±0.46	1.22±1.26	0.95±0.45
C18:1n9t	0.30±0.03	0.63±0.19	0.09±0.01	0.38±0.06	0.34±0.05	0.24±0.03
C18:1n9c	40.51±2.01	31.18±2.05	22.57±5.52	18.84±1.96	12.31±1.01	13.06±1.87
C20:1n9	1.22±0.12	1.05±0.14	0.90±0.17	1.40±0.11	0.58±0.19	0.51±0.09
C22:1n9	0.09±0.01	0.03±0.01	0.48±0.09	0.06±0.00	0.08±0.07	0.08±0.02
C24:1	0.08±0.01	0.02±0.00	1.47±0.06	0.11±0.03	0.51±0.17	0.57±0.17
C18:2n6t	0.01±0.00	0.06±0.02	0.07±0.05	0.02±0.01	0.04±0.05	0.03±0.03
C18:2n6c	3.15±0.34	4.73±0.39	5.32±0.66	2.74±0.17	2.69±0.96	2.66±0.67
C18:3n6	0.06±0.02	0.13±0.05	0.07±0.03	0.07±0.01	0.10±0.05	0.12±0.04
C18:3n3c	2.40±0.21	3.97±0.26	3.57±0.71	3.35±0.52	1.55±0.28	1.73±0.44
C18:4 n3	0.11±0.04	0.19±0.11	2.35±0.95	0.36±0.20	0.21±0.12	0.37±0.14
C20:2n6	0.79±0.05	1.43±0.27	1.25±0.11	1.54±0.16	0.57±0.06	0.53±0.07
C20:3n6	0.19±0.04	0.31±0.05	0.04±0.02	0.28±0.03	0.16±0.05	0.15±0.01
C20:3n3	0.45±0.03	0.62±0.04	0.40±0.04	0.68±0.10	0.24±0.13	0.29±0.04
C20:4n6	1.39±0.22	2.90±0.08	0.69±0.12	4.55±0.90	4.27±1.73	4.66±0.57
C22:2	0.05±0.00	0.05±0.01	0.140±0.02	0.05±0.01	0.04±0.01	0.10±0.14
C20:5n3	2.46±0.18	5.00±0.83	7.08±1.45	5.85±0.21	6.34±0.57	6.21±0.52
C22:5n3	2.45±0.22	1.65±0.27	0.57±0.05	3.09±0.50	2.38±0.61	2.08±0.13
C22:6n3	4.97±0.51	5.96±0.65	17.80±4.95	19.82±2.78	31.02±3.04	33.25±3.31

TABLE 3. Content of selected groups of fatty acids (%) in fat fish from the Vistula Lagoon.

Species	Eel	Bream	Herring	Roach	Perch	Pike perch
Σ SFA	29.34±0.50	26.44±1.10	29.44±1.36	25.10±1.73	26.81±3.23	25.51±2.22
Σ MUFA	52.17±1.36	46.50±1.96	31.20±6.36	32.49±3.14	23.59±1.84	22.30±2.95
Σ PUFA	18.49±1.23	27.01±1.17	39.35±7.58	42.41±3.20	49.60±4.28	52.19±2.88
Σ n-3	12.84±1.04	17.39±1.55	31.77±7.86	33.15±2.49	41.74±3.51	43.93±3.27
Σ n-6	5.59±0.52	9.56±0.82	7.44±0.45	9.20±0.97	7.83±2.35	8.15±0.44
n-6/n-3	0.44±0.06	0.55±0.08	0.23±0.08	0.28±0.02	0.19±0.06	0.18±0.02
DHA+EPA	7.43±0.62	10.96±1.20	24.88±6.18	25.67±2.65	37.36±3.45	39.46±3.71
*DHA+EPA	2.21±0.27	0.34±0.09	0.65±0.14	0.20±0.04	0.17±0.009	0.15±0.05
PUFA/SFA	0.63±0.05	1.02±0.04	1.34±0.31	1.69±0.19	1.85±0.035	2.04±0.24

* g/100 g meat

of lean fish (pikeperch, roach, perch) from the Vistula Lagoon are predominated by PUFAs, which constitute from 42.4 to 52.2%. Similar contents of PUFAs are reported by Orban *et al.* [2007] for perch from Italian lakes (42.1%) and by Guler *et al*. [2007] for pikeperch from Turkish lakes (54.2%). However, Õzogul *et al.* [2007a] reported the content of PUFAs in freshwater fish in the range of 23.2-43.8%. The most valuable fatty acids are EPA and DHA. The total contents of EPA and DHA in 100 g of muscle tissue of the fish examined in the current study was as follows: eel – 2.11 g, herring – 0.62 g, bream – 0.33 g, roach – 0.19 g, perch – 0.16 g, and pikeperch – 0.14 g (Table 3). The recommended daily dose of EPA and DHA for healthy persons (0.5 g) is contained in 24 g of eel, in 81 g of herring, in 151 g of bream, in 263 g of roach, in 312 g of perch, and in 357 g of pikeperch. For cardiovascular patients, this dose should be twofold higher. Data in the literature regarding freshwater fish (bream, pike, rapfen) from northern Polish lakes (0.10-0.31 g/100 g meat) indicate similar quantities of these acids [Żmijewski *et al*., 2006], while in pikeperch they are reported to be 0.18 g/100 g meat [Guler *et al*., 2007]. Marine fish species, such as the sardine, anchovy, and picarel, contain substantially higher quantities of EPA and DHA in the range of 1.75 to 2.86 g/100 g meat [Kunachowicz *et al*., 1998]. The high content of DHA in the lipids of pikeperch (33.25%), perch (31.02%), roach (19.82%), and herring (17.8%) must be underscored. DHA and EPA were the dominant acids from the n-3 family.

The total of n-3 acids in the examined fish ranged from 12.84% in eel oil to 43.93% in pikeperch fat. Acids from the n-3 family help prevent cardiac disorders by diminishing the negative impact of PUFAs from the n-6 family [Steffens, 1997]. The share of n-6 acids in the fish examined was low and was within the range of 5.59-9.56% of the total fatty acids (Table 3). Nutritionists emphasize the significance of maintaining a low n-6/n-3 ratio in diets to prevent arteriosclerosis. The UK Department of Health recommends a maximum n-6/n-3 dietary ratio of 4.0 [HMSO, 1994]. Since this ratio in food is generally higher, fish consumption is excellent at lowering it. The values of this proportion in the Vistula Lagoon fish examined in the current study were 0.19 for perch, 0.18 for pikeperch, 0.28 for roach, 0.23 for herring, 0.44 for eel, and 0.55 for bream. Reports in the literature cite values of n-6/n-3 in freshwater fish within the range of 0.21-1.0 and for marine fish of 0.009-0.59 [Õzogul *et al*., 2007a]. The consumption of Vistula Lagoon fish has an advantageous impact on maintaining the overall dietary n-6/n-3 ratio at the recommended level. Another important factor in the prevention of cardiovascular disease is the ratio of PUFA/SFA. The UK Department of Health recommends a minimum value of this coefficient of 0.45 [HMSO, 1994]. The value of the fish from the Vistula Lagoon is higher at 0.63 for eel, 1.02 for bream, 1.34 for herring, 1.69 for roach, 1.85 for perch, and 2.04 for pikeperch. Õzogul *et al.* [2007a] reported PUFA/SFA values for freshwater fish within the range of 0.78-1.56 and for marine fish within the range of 0.66-1.85.

CONCLUSIONS

1. Fish from the Vistula Lagoon are rich in essential unsaturated fatty acids from the n-3 family, especially DHA.
2. The fish examined had a low n-6/n-3 ratio, which is why their consumption has an advantageous impact on maintaining the recommended dietary level of this coefficient.
3. The PUFA/SFA coefficient exceeded the recommended minimum value of 0.45 and was within the range of 0.63-2.04.
4. The parameters above evidence that the fish from the Vistula Lagoon are of a high nutritive value and are a healthy addition to the diet.

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REFERENCES

1. Ackman R.G., McLeod C., Rakshit S., Misra K.K., Lipids and fatty acids of five freshwater food fishes of India. J. Food Lipids, 2002, 9, 127–145.

2. Alasalvar C., Taylor K.D., Zubcov E., Shahidi F., Alexis M., Differentiation of cultured and wild sea bass (*Dicentrarchus labrax*): total lipid content, fatty acid and trace mineral composition. Food Chem., 2002, 79, 145–150.
3. Falandysz J., Wyrzykowska B., Warzocha J., Barska I., Garbacik-Wesołowska A., Szefer P., Organ chlorine pesticides and PCB_s in perch *Perca Fluviatilis* from the Odra/Oder river estuary, Baltic Sea. Food Chem., 2004, 87, 17–23.
4. Gökçe M.A., Taşbozan O., Çelik M., Tabakoglu Ş.S., Seasonal variations in proximate and fatty acid compositions of female common sole (*Solea solea*). Food Chem., 2004, 88, 419–423.
5. González S., Flick G.J., O'Keefe S.F., Duncan S.E., McLean E., Craig S.R., Composition of farmed and wild yellow perch *(Perca flavescens*). J. Food Compos. Anal., 2006, 19, 720–726.
6. Guler G.O., Aktumsek A., Citil O.B., Arslan A., Torlak E., Seasonal variations on total fatty acid composition of fillets of zander (*Sander lucioperca*) in Beysehir Lake (Turkey). Food Chem., 2007, 103, 1241–1246.
7. Haliloglu H.Í., Bayir A., Sirkecioglu A.N., Aras N.M., Atamanalp M., Comparison of fatty acid composition in some tissues of rainbow trout (*Oncorhynchus mykiss*) living in seawater and freshwater. Food Chem., 2004, 86, 55–59.
8. HMSO, UK., Nutritional aspects of cardiovascular disease (report on health and social subjects, 1994, No. 46) London: HMSO.
9. Kinsella J.E., Fish and sea food: nutritional implications and quality issues. Food Technol., 1988, 42, 146–150.
10. Krajnovic-Ozretic M., Najdek M., Ozretic B., Fatty acid in liver and muscle of farmed and wild sea bass (*Dicentrarchus labrax L.*). Comp. Biochem. Physiol. A, 1994, 109, 611–617.
11. Kris-Etherton P.M., Harris W.S., Appel L.J., Fish consumption, fish oil, omega-3 fatty acids and cardiovascular disease. Circulation, 2002, 106, 2747–2757.
12. Kunachowicz H., Nadolna I., Przygoda B., Iwanow K., Tables of nutritive values of food products. 1998, Instytut Żywności i Żywienia, Warszawa (in Polish).
13. Méndez E., González R.M., Inocente G., Giudice H., Grompone M.A., Lipid content and fatty acid composition of fillets of six fishes from the Rio de la Plata. J. Food Compos. Anal., 1996. 9, 163–170.
14. Orban E., Nevigato T., Masci M., Di Lena G., Casini I., Caproni R., *et al*., Nutritional quality and safety of European perch (*Perca fluviatilis*) from three lakes of Central Italy. Food Chem., 2007, 100, 482–490.
15. Õzogul Y., Õzogul F., Fatty acid profiles of commercially important fish species from the Mediterranean, Aegean and Black Seas. Food Chem., 2007, 100, 1634–1638.
16. Õzogul, Y., Õzogul F., Alagoz, S., Fatty acid profiles and fat contents of commercially important seawater and freshwater fish species of Turkey: A comparative study. Food Chem., 2007, 103, 217–223.
17. Polish Standard PN-A-86770: 1999. Fish and fishery products – terminology. (in Polish).
18. Psuty-Lipska I., Draganik B., Fishery practice versus experimental design: Preliminary results of the introduction of protective sieves in the eel fyke-net fishery of the Vistula Lagoon, Poland. Fish. Res., 2005, 76, 146–154.
19. Psuty-Lipska I., Evaluation of fish assemblages changes from Polish brackish lagoons as an impact of fishery exploitation and species succession. Raporty Morskiego Instytutu Rybackiego, 2006, Morski Instytut Rybacki, Gdynia, 13–14, (in Polish).
20. Rasoarahona J.R.E., Barnathan G., Bianchini J-P., Gaydou E. M., Influence of season on the lipid content and fatty acid profiles of three tilapia species (*Oreochromis niloticus, O.macrochir* and *Tilapia rendalli*) from Madagascar. Food Chem., 2005, 91, 683–694.
21. Steffens W., Effects of variation in essential fatty acids in fish feeds on nutritive value of freshwater fish for humans. Aquaculture, 1997, 151, 97–119.
22. Vasilopoulou E., Georga K., Grilli E., Linardou A., Vithoulka, M., Trichopoulou A., Compatibility of computed and chemically determined macronutrients and energy content of traditional Greek recipes. J. Food Compos. Anal., 2003, 16, 707–719.
23. Zlatanos S., Laskaridis K., Seasonal variation in the fatty acid composition of three Mediterranean fish – sardine (*Sardina pilchardus*), anchovy (*Engraulis ercrasicholus*) and picarel (*Spicara smaris*). Food Chem., 2007, 103, 725–728.
24. Żmijewski T., Kujawa R., Jankowska B., Kwiatkowska A., Mamcarz A., Slaughter yield, proximate and fatty acid composition and sensory properties of rapfen (*Aspius aspius L*) with tissue of bream (*Abramis brama L*) and pike (*Esox lucius L*). J. Food Compos. Anal., 2006, 19, 176–181.

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