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INTERSPECIFIC DIFFERENCES IN THE CONTENTS OF MACRO- AND MICROELEMENTS IN THE MUSCLE OF SIX FISH SPECIES FROM LAKES OF THE OLSZTYN LAKE DISTRICT (NORTH-EAST OF POLAND)

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Key words: macroelements, microelements, freshwater fish, muscle tissue, interspecific differences

Muscles of roach (*Rutilus rutilus* L.), bream (*Abramis brama* L.), perch (*Perca fluviatilis* L.), pike (*Esox lucius* L.), vendace (*Coregonus albula* L.) and whitefish (*Coregonus lavaretus* L.) from lakes of the Olsztyn Lake District were examined for the content of macroelements (Mg, Ca, Na, K and P) and microelements (Fe, Zn, Cu and Mn). The fish were caught over the period from October 1999 to October 2000. There were significant interspecific differences in the contents of dietary elements. The highest magnesium (26.7 mg/100 g), calcium (36.5 mg/100 g) and phosphorus (230.6 mg/100 g) concentrations were found in the muscle of roach. A significantly higher content of Mg was observed in the muscle of pike (27.6 mg/100 g) and perch (26.5 mg/100 g). The concentration of Na (47.0 mg/100 g) in muscle tissue of perch was higher than in that of the other fish species. The significantly higher contents of Fe (2.81 mg/kg), Cu (0.315 mg/kg) and Mn (0.167 mg/kg) were found in muscle of vendace. In the muscle tissue of pike, the concentrations of zinc (8.41 mg/kg) were higher compared with other species.

INTRODUCTION

Fish is not only a source of valuable proteins and specific n-3 and n-6 polyenoic fatty acids, but it also provides necessary mineral macro- and microelements. Calcium, magnesium and phosphorus are good building material, they form structural elements of bones and other tissues. Sodium and potassium regulate water management and acid-base balance in blood and tissues as well as take part in maintaining the resting potential of cell membranes [Report of the Scientific Committee for Food, 1993; Brzozowska 2000]. Microelements (iron, zinc, copper and manganese) are found in physiological concentrations and are essential for living organisms. Likewise, some macroelements are important components of enzymes, crucial to vital functions of humans and animals, and their deficit or excess may cause numerous illnesses [Food and Nutrition Board Institute of Medicine, 2001]. Iron, zinc and copper are included in the group of the essential trace elements, but they are also heavy metals.

Such metals as iron, zinc, copper and manganese enter the aquatic environment by various routes, *e.g.* by the erosion of the native rock the soil originated from or from anthropogenic sources [Alloway & Ayres, 1999]. They then accumulate in bottom deposits and in organisms which inhabit the hydrosphere [Radwan *et al.*, 1990a, b; Pourang, 1995]. Calcium and magnesium can penetrate into surface water due to intensive washing from soils, supplied with fertilizers. Phosphorus content in fertilizers and detergents also results in the intensive contamination of surface waters [Kajak, 2001]. Sodium and chlorides increase in lakes polluted with domestic sewage [Szczerbowski & Zdanowski, 1993].

Macro- and microelement contents of muscle tissue of fish are self-regulated; however, their values can be different because of certain biological conditions, such as species, sex, age, and feeding [Håkanson, 1984]. Polish and foreign literature provides data on microelements in marine and freshwater fish, whereas, in most cases, the data concern the concentration of macroelements in marine fish. Consequently, the objective of this study was to determine the differences between species in terms of the concentrations of minerals (macro- and microelements) in the muscle tissue of six freshwater fish species that inhabit four lakes of the Olsztyn Lake District (Łańskie, Pluszne, Dłużek and Maróz).

MATERIAL AND METHODS

In this study, fish samples of roach (*Rutilus rutilus* L.), bream (*Abramis brama* L.), perch (*Perca fluviatilis* L.), pike (*Esox lucius* L.), vendace (*Coregonus albula* L.) and whitefish (*Coregonus lavaretus* L.) were caught from four lakes of the Olsztyn Lake District, Poland (Figure 1). Fish were collected from October 1999 to October 2000. The samples were taken to the laboratory at the day of catch, where they were weighed and the fork length of each fish was measured. The number of fish, their weight and length are given

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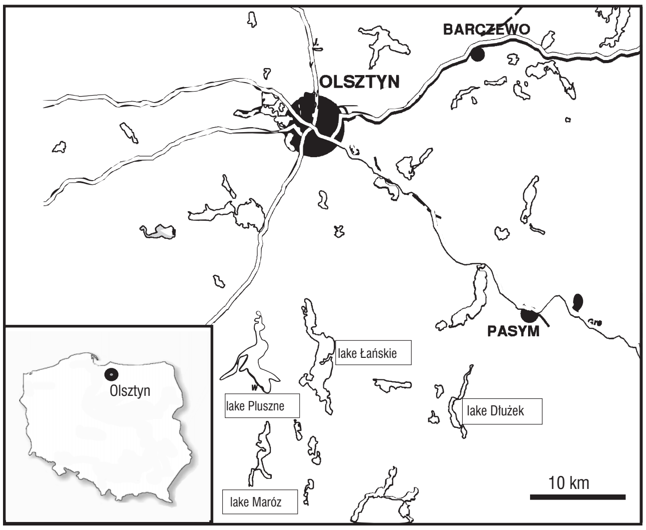

FIGURE 1. Sampling area.

in Table 1. Samples of the muscle tissue were taken from the dorsal part and mixed, then they were kept in polypropylene bags at 248K (-25°C) until analysed. In the case of small perch and roach from the four studied lakes (body weight <160 g), the samples were prepared from muscle tissues taken from two-nine specimens of approximately the same size. Whereas, in the case of large perch and roach, each sample was prepared from the tissue taken from one or two fish. For vendace, samples were prepared from muscles taken from four, five, six, seven, eight or nine fish. In the case of bream, whitefish and pike, each sample was prepared only from the muscles taken from one fish.

Approximately 10 g samples of muscle in duplicate were initially dried at 338–343 K (65–70°C) in quartz tests, then dried to a constant weight at 378 K (105°C). The samples of muscles were dry-digested at 573 K (300°C) for 6 h, after which the temperature was gradually raised to 723 K (450°C). The white ash was dissolved in 1 mol/L HNO_3 (Suprapur-Merck) and each sample was quantitatively

TABLE 1. Body weight and total length of the freshwater fish species studied.

Species/Lake	n	Number of fish	Body weight (g)		Total length (cm)	
			range	$\bar{x}$ ± SD	range	$\bar{x}$ ± SD
Roach (*Rutilus rutilus* L.)						
Łańskie	12	48	42–342	156.0±117.3	15.8–29.0	21.9±5.3
Pluszne	12	38	36–532	273.6±221.0	15.5–33.4	25.3±7.4
Dłużek	12	49	26–540	236.3±214.1	14.1–35.0	24.3±9.2
Maróz	12	43	38–445	213.2±175.6	15.4–32.0	23.6±6.9
	48	178	26–540	219.8±185.6	14.1–35.0	23.8±7.2
Bream (*Abramis brama* L.)						
Łańskie	12	12	370–1552	942.9±423.5	31.8–47.6	40.4±5.2
Pluszne	12	12	502–1612	876.5±329.5	35.6–50.1	41.3±4.6
Dłużek	12	12	284–1500	867.4±366.2	29.8–48.0	40.2±5.6
Maróz	12	12	520–1614	1062.2±402.2	34.5–48.8	42.5±4.9
	48	48	284–1614	937.3±377.9	29.8–50.1	41.1±5.0
Perch (*Perca fluviatilis* L.)						
Łańskie	12	37	36–584	247.0±216.9	14.6–33.6	23.3±7.4
Pluszne	12	36	40–766	383.2±301.9	15.9–36.1	27.4±7.7
Dłużek	12	52	22–862	349.4±331.8	12.6–36.8	24.0±9.6
Maróz	12	31	46–927	339.4±304.5	15.7–38.7	25.9±8.9
	48	156	22–927	329.8±287.1	12.6–38.7	25.1±8.3
Pike (*Esox lucius* L.)						
Łańskie	12	12	155–2682	1115.5±805.4	28.7–71.9	49.8±13.9
Pluszne	12	12	744–2012	1241.1±449.9	48.0–63.5	55.5±6.2
Dłużek	12	12	684–5235	1782.5±1451.7	44.4–92.0	57.5±14.0
Maróz	12	12	571–1854	1035.7±474.8	43.5–65.1	52.3±8.9
	48	48	155–5235	1271.8±927.7	28.7–92.0	53.8±11.3
Vendace (*Coregonus albula* L.)						
Łańskie	6	34	72–218	104.4±27.4	21.5–30.1	24.2±1.5
Pluszne	6	40	46–86	57.9±4.7	18.1–23.1	20.4±0.5
Dłużek	6	46	38–78	51.6±2.8	17.0–21.6	19.2±0.4
Maróz	6	44	52–100	69.4±4.2	19.1–23.7	21.3±0.3
	24	164	38–218	70.9±24.6	17.0–30.1	21.2±2.0
Whitefish (*Coregonus lavaretus* L.)						
Łańskie	6	6	396–672	517.7±102.3	36.0–40.0	37.7±1.43
Pluszne	6	6	564–1130	803.7±202.4	38.4–46.2	42.5±2.7
Dłużek	6	6	384–610	536.3±83.4	33.0–38.1	36.5±1.9
Maróz	6	6	372–534	440.7±57.7	34.0–36.6	35.4±0.9
	24	24	372–1130	574.6±181.7	33.0–46.2	38.0±3.3

Means values and standard deviations are given as $\bar{x}$ ± SD; n – number of samples transferred with deionized water (MILLIPORE) to a 25 mL glass volumetric flask. All flasks were washed with 10% HNO_3 (Suprapur-Merck) prior to use, then thoroughly rinsed with deionized water.

All samples were processed in duplicate. Three blanks and four standards were analysed with each batch of samples. Microelements (iron, zinc, copper and manganese) and macroelements (magnesium and calcium) were analysed by means of the flame atomic absorption spectrometry (UNICAM Solar 939) with correction by the use of a deuterium lamp. The absorption wavelengths were as follows: 248.3 nm for iron, 213.9 nm for zinc, 324.8 nm for copper, 279.5 nm for manganese, 285.2 nm for magnesium and 422.7 nm for calcium. The detection limits were: 0.125 mg/kg for Fe, 0.1 mg/kg for Zn, 0.05 mg/kg for Cu, 0.05 mg/kg for Mn, 0.025 mg/kg for Mg, and 0.5 mg/kg for Ca; whereas, the sensitivities were: 0.05 mg/L, 0.05 mg/L, 0.02 mg/L, 0.02 mg/L, 0.01 mg/L, and 0.2 mg/L, respectively. During determination of calcium, in order to eliminate the influence of phosphorus, the solution of lantanum chloride was added (in amount assuring 1% concentration of La^{+3} in the solution analysed) to all of samples and standards [Whiteside & Miner, 1984]. Sodium and potassium were determined by the emission flame photometry (FLAPHO 4, Carl Zeiss Jena) at 589.0 nm and 766.5 nm, respectively [Rutkowska, 1981]. Phosphorus was measured with the colourimetric method of Mattsson & Swartling [1954]. The absorbance of phosphorus was determined at 610 nm (VIS 6000 SPECTROPHOTOMETER). The detection limits were 1 mg/kg for Na, 5 mg/kg for K, and 12 mg/kg for P; whereas the sensitivities were: 0.5 mg/L, 2 mg/L and 5 mg/L, respectively.

The reliability of the analytical methods was examined by measuring the elements in reference material: CRM 422 – cod muscle tissue (lyophilised sample) with a certified concentration of Zn, Fe, Cu and Mn [Quevauviller *et al.*, 1993]. The standard reference materials were analysed with each batch of samples. The recovery rates of these elements were: 105% Zn, 96% Fe, 103% Cu and 103% Mn.

Statistical analysis. The contents of Fe, Zn, Cu and Mn in fish are expressed in mg/kg of wet weight and the concentrations of Mg, Ca, Na, K and P are expressed in mg/100 g of wet weight. The statistical analysis was carried out with the use of STATISTICA PL software. In most cases of statistical analysis, Bartlett's test showed that the variances were heterogeneous; therefore mean values in particular groups were transformed (log $\bar{x}$). The one-way ANOVA (Duncan's test) at a level of significance of $p \leq 0.01$ and $p \leq 0.05$ was used to find interspecific differences [Babiak, 1998].

RESULTS

Magnesium, calcium, sodium, potassium and phosphorus

The fish included in the study differed considerably in terms of the content of some mineral components (Figures 2 and 3). Pike and roach ($p \leq 0.01$) as well as perch ($p \leq 0.05$) proved a significantly richer source of magnesium than bream. Concentrations of magnesium in the muscles of vendace (15.5 mg/100 g) and whitefish (15.9 mg/100 g) were lower by nearly 1/3 ($p \leq 0.01$) than in the other species. The mean content of magnesium in the muscles of the other fish ranged from 23.9 mg/100 g (bream) to 27.6 mg/100 g (pike).

Predatory fish (perch and pike) and bream contained significantly less calcium (18.2 mg/100 g, 20.8 mg/100 g and 19.6 mg/100 g, respectively) than roach, vendace and whitefish ($p \leq 0.01$). The highest mean concentration of calcium (Figure 2) was found in roach and whitefish (36.5 mg/100 g and 34.1 mg/100 g); whereas a significantly lower calcium content than in the muscles of roach ($p \leq 0.01$) and whitefish ($p \leq 0.05$), was found in the muscle tissue of vendace (29.1 mg/100 g).

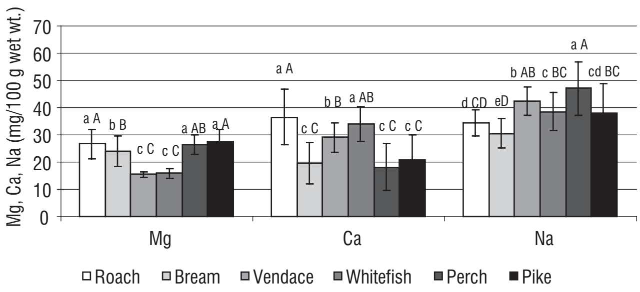

FIGURE 2. Concentrations of Mg, Ca and Na (mean ± standard deviation) in muscle tissue of six fish species from lakes of the Olsztyn Lake District.
n=48 in the case of roach, bream, perch and pike, n=24 in the case of vendace and whitefish; a, b, c, d, e – significant difference ($p \leq 0.05$); A, B, C, D, E – significant difference ($p \leq 0.01$). The same letter indicates the absence of significant differences between the sampling sites.

As for sodium (Figure 2), a significantly higher concentration (47.0 mg/100 g) was found in the muscles of perch as compared with roach, bream, whitefish and pike ($p \leq 0.01$) as well as vendace ($p \leq 0.05$), whereas the concentrations of that element were the lowest in bream (30.4 mg/100 g). The mean concentrations of sodium in the muscles of the fish under study were: 34.5 mg/100 g (roach), 38.6 mg/100 g (whitefish), 42.4 mg/100 g (vendace), and 38.0 mg/100 g (pike).

The differences between the mean values for potassium and phosphorus were relatively small; however, with such a low degree of dispersion within species they proved to be statistically significant (Figure 3). For potassium, only in the

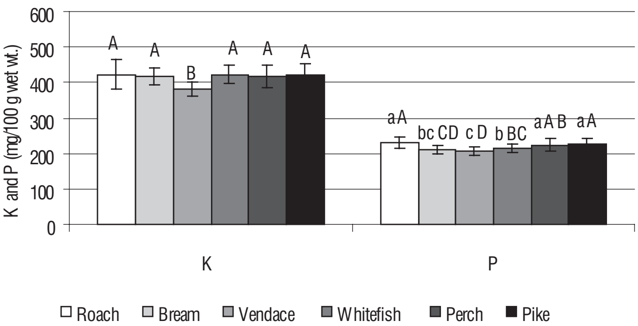

FIGURE 3. Concentrations of K and P (mean ± standard deviation) in muscle tissue of six fish species from lakes of the Olsztyn Lake District.
n=48 in the case of roach, bream, perch and pike, n=24 in the case of vendace and whitefish; a, b, c, d – significant difference ($p \leq 0.05$); A, B, C, D – significant difference ($p \leq 0.01$). The same letter indicates the absence of significant differences between the sampling sites.

muscles of vendace was the concentration of this element (382.2 mg/100 g) significantly lower than in the other species ($p \leq 0.01$). The mean concentrations of potassium in the muscles of the other fish species ranged from 416.6 mg/100 g (bream) to 423.2 mg/100 g (whitefish). The mean concentration of phosphorus ranged from 204.9 mg/100 g (vendace) to 230.6 mg/100 g (roach). No difference was found in terms of concentrations of phosphorus between the species within the following groups (roach, perch and pike) – (whitefish and perch) – (bream and whitefish) – (bream and vendace) ($p > 0.01$) and (roach, perch and pike) – (bream and whitefish) – (bream and vendace) ($p > 0.05$).

Iron, zinc, copper and manganese

In the group of the species under study, vendace stands out (Figures 4 and 5) as containing more iron (2.81 mg/kg), copper (0.315 mg/kg) and manganese (0.167 mg/kg) than the other fish species ($p \leq 0.01$). The iron content of fish muscles was affected by the feeding type (Figure 4), as significantly lower concentrations of that element (1.05 mg/kg and 0.985 mg/kg) were found in predatory fish (perch and pike, respectively). The mean concentrations of iron in the muscles of fish included in this study gave rise to the following sequence: vendace > roach ≈ bream ≈ whitefish > perch ≈ pike ($p \leq 0.01$) and vendace > roach > bream ≈ whitefish > perch ≈ pike ($p = 0.05$).

In terms of zinc content (Figure 4), the muscles of pike were characterised by a higher content of this element (8.41 mg/kg) than bream and whitefish (3.07 mg/kg and 3.11 mg/kg, respectively) ($p \leq 0.01$). The mean concentration of zinc in the muscles of the other fish species accounted for: 5.05 mg/kg (roach), 5.21 mg/kg (vendace), and 4.42 mg/kg (perch). The mean concentrations of zinc in the muscles of fish included in this study gave rise to the following sequence ($p \leq 0.05$): pike > vendace ≈ roach > perch > whitefish ≈ bream.

The mean concentration of copper in the muscles of roach, bream, whitefish, perch and pike ranged from 0.179 mg/kg to 0.214 mg/kg (Figure 5). The non-predatory fish (roach and bream) contained more copper, similar to vendace ($p \leq 0.01$), than the predatory fish (perch and pike). The mean concentrations of copper in the muscles of the fish under study gave rise to the following sequence: vendace > roach ≈ bream > whitefish ≈ pike ≈ perch ($p \leq 0.05$).

The muscles of perch proved to be the least abundant source of manganese (0.071 mg/kg) ($p \leq 0.01$). The mean concentrations of manganese in the muscles of roach, bream, whitefish and pike were: 0.117 mg/kg, 0.096 mg/kg, 0.104 mg/kg and 0.094 mg/kg, respectively. The results of the significance analysis of the differences between the mean concentrations of manganese in the fish muscles enabled creating four groups of fish which did not differ in terms of the concentration of this element (Figure 5): (vendace) – (roach, bream and whitefish) – (bream, whitefish and pike) – (perch) ($p > 0.01$) and (vendace) – (roach and whitefish) – (bream, whitefish and pike) – (perch) ($p > 0.05$).

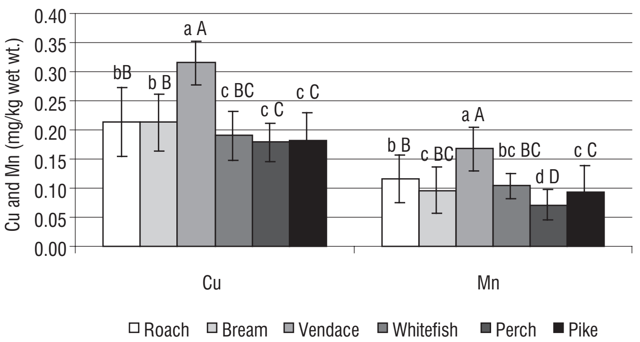

FIGURE 5. Concentrations of Cu and Mn (mean ± standard deviation) in muscle tissue of six fish species from lakes of the Olsztyn Lake District.
n=48 in the case of roach, bream, perch and pike, n=24 in the case of vendace and whitefish; a, b, c, d – significant difference ($p \leq 0.05$); A, B, C, D – significant difference ($p \leq 0.01$). The same letter indicates the absence of significant differences between the sampling sites.

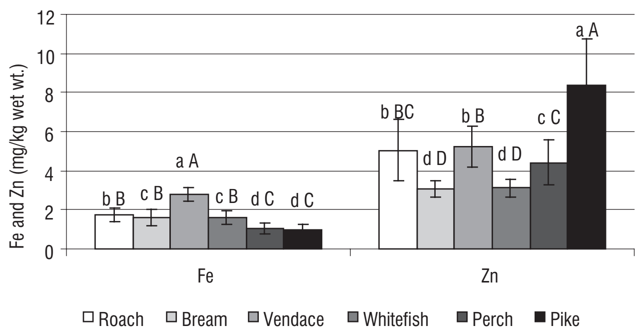

FIGURE 4. Concentrations of Fe and Zn (mean ± standard deviation) in muscle tissue of six fish species from lakes of the Olsztyn Lake District.
n=48 in the case of roach, bream, perch and pike, n=24 in the case of vendace and whitefish; a, b, c, d – significant difference ($p \leq 0.05$); A, B, C, D – significant difference ($p \leq 0.01$). The same letter indicates the absence of significant differences between the sampling sites.

DISCUSSION

The differences between the concentrations of most macroelements in the muscles of fish were affected by the fish species. The results obtained in this study are consistent with the results of other studies into freshwater fish. One of the examples is the wide range of calcium concentrations determined by Vlieg *et al.* [1991] in freshwater fish from aquatic ecosystems in New Zealand, which indicates strong interspecific differences. Other authors observed such differences for calcium and manganese, sodium and potassium in the fish species typical of the waters of Sri Lanka [Wimalasena & Jayasuriya, 1996]. It is noteworthy that the lowest concentration of calcium (47.3 mg/100 g) was found by those authors in the muscles of Mozambique tilapia (*Oreochromis mossambicus*), whereas the highest (650.0 mg/100 g) was in the muscles of Indian catfish (*Heteropneustes fossilis*). Chandrashekar & Deosthale [1993] conducted a study on freshwater fish bought in the Indian market and found considerable differences within the species included in the study not only for the concentration of magnesium and calcium, but also for phosphorus. Similarly, Belinsky *et al.* [1996] observed a difference in the concentration of calcium in the muscles of fish caught in Canadian lakes. The lowest concentration of calcium was found in the muscles of lake trout (*Salvelinus namaycush*), whereas the highest concentration of the element was found in the muscles of brook trout (*Salvelinus fontinalis*). The authors also found similar concentrations of calcium in the muscles of pike (7.0 mg/100 g and 8.0 mg/100 g) caught in two reservoirs (Vermeulle and Dollier). The mean concentration of calcium (20.82 mg/100 g) determined in the muscles of pike included in this study (Figure 2) was much higher than the values found in an earlier study by Belinsky *et al.* [1996].

The highest content of magnesium (Figure 2) in the muscles of pike is consistent with the results obtained by Kownacki & Doboszyńska [1976]. According to these researchers, among the 5 freshwater species (carp, tench, zander, pike and eel) it is pike which contained the highest amounts of magnesium (21.5 mg/100 g), while the lowest concentrations of that element were found in carp. The concentration of magnesium in the muscles of perch included in this study (Figure 2) was similar, whereas that of potassium (Figure 3) was a little lower than that found by Falandysz [1992]. The results for the concentration of calcium and sodium in the muscles of the perch (Figure 2) were over twice as low as those obtained by that author.

Apart from the macroelements, the study also dealt with the concentrations of microelements essential for the functioning of an organism. The feeding type (predatory and non-predatory fish) significantly affected the concentration of iron in the muscles of fish included in the study (Figure 4). This element was found in lower amounts in pike and perch than in the other fish. These findings did not confirm the results obtained by Radwan *et al.* [1990b], who found the muscles of pike to contain the lowest amounts of iron (15.0 mg/kg dry weight). The same authors found the highest concentrations of the element in the muscles of perch (30.0 mg/kg dry weight). The values obtained for iron in the muscles of pike included in the study was similar to the level of iron in the muscles of pike found by Belinski *et al.* [1996]. Unlike the study conducted by Protasowicki *et al.* [1983], in the current study the feeding type did not significantly affect the concentration of zinc (Figure 4) or copper (Figure 5). The same authors found the highest concentrations of the elements in the planktonovorous fish, followed by cultured, benthosovorous and predatory fish. Taking into account the level of zinc accumulation in the muscles of fish from the lakes which are part of the Pasvik River system (on the border between Norway and Russia), Amundsen *et al.* [1997] created a decreasing series: whitefish (*C. lavaretus lavaretus*) > vendace (*Coregonus albula*) ≈ pike (*Esox lucius*) > burbot (*Lota lota*) > brown trout (*Salmo trutta m. fario*) > whitefish (*C. lavaretus pidschian*) ≈ perch (*Perca fluviatilis*) ($p<0.05$). Conversely, the whitefish (*C. lavaretus*) from the Olsztyn Lake District (Figure 4) contained smaller amounts of zinc than the muscles of pike. Interspecific differences in zinc concentration in fish (4.56 mg/kg – 26.89 mg/kg) were also observed by Sangiorgi & Ferretti [1993].

The finding of the highest concentrations of zinc in the muscles of pike (8.41 mg/kg) confirmed the results of earlier research by Johnson [1987]. The author observed that the muscles of pike (*Esox lucius*) from Lake Ontario contained the highest concentrations of the metal, while in those of lake trout (*Salvelinus namaycush*) and walleye (*Stizostedion vitreum*), the concentrations were the lowest.

No differences between predatory and non-predatory fish in terms of the concentration of copper were found in the study by Rehulká [2002], which included ten fish species. An analysis of the level of manganese (Figure 5) in the muscles of three fish species (bream, perch and pike) showed that the highest concentrations were also found by Radwan *et al.* [1990b]. The same authors determined that mean content of manganese in fish muscles to range from 0.7 mg/kg dry weight (bream) to 2.6 mg/kg dry weight (perch).

The average per capita consumption of fish in Poland in 2001 (in the households included in the survey by the Central Office of Statistics) amounted to 5.16 kg/year, which corresponds to a weekly consumption of 0.0992 kg, and a daily consumption of 0.014 kg [Rejn, 2003]. According to estimations by Panczenko-Kresowska & Ziemlański [2001], the recommended dietary allowances (RDA) of iron, zinc and magnesium per capita equal: 15 mg, 16 mg and 370 mg, respectively (for adult men) or 18 mg, 13 mg and 300 mg (for adult women). Whereas, in the case of calcium and phosphorus they equal 900 mg and 700 mg per capita (for adults). In the case of copper, the safe level of intake per capita is 2.0–2.5 mg (for adults). In respect of the highest mean concentration of iron and copper of 2.81 mg/kg and 0.315 mg/kg in the muscles of vendace, it was calculated that the fish would provide 0.039 mg Fe a day or 0.004 mg Cu a day, which accounts for as little as 0.26% and 0.22% of RDA (adult men and women, respectively) or 0.18–0.22% of the safe level of intake, respectively. Knowing that the highest concentrations of zinc (8.41 mg/kg) and magnesium (27.6 mg/100 g) were found in the muscles of pike, it was calculated that an average Pole would take in up to 0.118 mg Zn daily or 5.111 mg Mg daily, which would account for 0.79% of RDA (adult men) and 0.91% of RDA (adult women) or 1.38% of RDA (adult men) and 1.70% of RDA (adult women), respectively. The highest contents of calcium (36.5 mg/100 g) and phosphorus (230.6 mg/100 g) were found in the muscles of roach, which accounts for 3.868 mg Ca daily and 32.284 mg P daily per capita (0.43% of RDA and 4.61% of RDA, respectively).

The lowest threshold intake (LTI) of potassium and sodium equals 3500 mg and 575 mg for adults, respectively. Whereas, the highest contents of K and Na were found in the muscle tissue of whitefish (423.2 mg/100 g) and perch (47.0 mg/100 g). The fish would provide 59.242 mg K a day and 6.58 mg Na a day, which accounts for 1.69% of LTI and 1.14% of LTI, respectively.

The report by the European Scientific Committee for Foods Research [European Commission Health & Consumer Protection Directorate-General, 2000] states that the tolerable intake of manganese with food amounts to 1 to 10 mg daily for an adult. With the highest concentration of manganese (0.167 mg/kg) found in the muscles of vendace and the mean consumption of fish in Poland of 0.014 kg/day it was calculated that a Pole would consume 0.0023 mg manganese a day, which would account for 0.23%–0.023% of daily tolerable intake of manganese with food. These data indicate that even the highest observed concentrations of iron, zinc and manganese do not pose any threat to humans and their amounts in fish can be regarded as natural.

CONCLUSIONS

The concentrations of macro- and microelements in the muscles of fish depend in most cases on the biological factors, such as the species. In the case of iron depends also on the feeding type because predatory fish contain less iron than non-predatory fish.

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MIĘDZYGATUNKOWE RÓŻNICE ZAWARTOŚCI MAKRO- I MIKROELEMENTÓW W TKANCE MIĘŚNIOWEJ SZEŚCIU GATUNKÓW RYB Z JEZIOR POJEZIERZA OLSZTYŃSKIEGO (PÓŁNOCNO-WSCHODNIA POLSKA)

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Zawartość makroelementów (Mg, Ca, Na, K i P) i mikroelementów (Fe, Zn, Cu i Mn) oznaczono w tkance mięśniowej płoci (*Rutilus rutilus* L.), leszcza (*Abramis brama* L.), okonia (*Perca fluviatilis* L.), szczupaka (*Esox lucius* L.), sielawy (*Coregonus albula* L.) i siei (*Coregonus lavaretus* L.), pochodzących z czterech jezior Pojezierza Olsztyńskiego. Ryby poławiano w okresie od października 1999 do października 2000. Stwierdzono istotne różnice w zawartości badanych pierwiastków w mięśniach ryb. Tkanka mięśniowa płoci charakteryzowała się najwyższym stężeniem magnezu (26,7 mg/100 g), wapnia (36,5 mg/100 g) i fosforu (230,6 mg/100 g) (rys. 2 i 3). Istotnie wyższą zawartość magnezu stwierdzono również w przypadku szczupaków (27,6 mg/100 g) i okoni (26,5 mg/100 g). Mięśnie okoni cechowały się najwyższą zawartością sodu (47,0 mg/100 g) w porównaniu z pozostałymi gatunkami ryb. Najwyższe stężenie żelaza (2,81 mg/kg), miedzi (0,315 mg/kg) i manganu (0,167 mg/kg) stwierdzono w tkance mięśniowej sielaw, zaś najwyższą zawartość cynku (8,41 mg/kg) odnotowano w mięśniach szczupaków (rys. 4 i 5).