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ORIGINAL PAPER

CONTENT OF MACRO- AND MICROELEMENTS IN THE MUSCLES OF GRASS CARP, BIGHEAD CARP, SIBERIAN STURGEON AND WELS CATFISH FROM EASTERN POLAND*

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Abstract

Knowledge of the levels of macro- and microelements in food fish is crucial in terms of both nutrition and health protection. The daily reference intakes of macronutrients and micronutrients for adults are defined in European legislation. However, minerals may have adverse effects on the body in quantities exceeding the body's requirements. Grass carp, bighead carp, Siberian sturgeon and wels catfish are food fish of commercial significance in many countries. The objective of the study was to determine the content of calcium (Ca), magnesium (Mg), copper (Cu), manganese (Mn), zinc (Zn), iron (Fe), chromium (Cr) and selenium (Se) in the muscles of grass carp, bighead carp, Siberian sturgeon and wels catfish and to compare these values with reference values. In addition, the estimated daily intake (EDI), target hazard quotient (THQ), and total target hazard quotient (TTHQ) were determined in order to assess the potential risk of a toxic effect of these elements on consumer health. Atomic absorption spectrometry was used to evaluate the content of Ca, Mg, Cu, Mn, Zn, Fe, Cr and Se. The average content of these elements (mg kg^{-1} WW) was as follows: Ca 68.02 - 894.9, Mg 97.60 - 226.0, Cu 0.36 - 1.15, Mn 0.25 - 0.34, Zn 5.78 - 7.09, Fe 4.29 - 6.73, Cr 0.08 - 0.33 and Se 0.02 - 0.05. The content of minerals in the muscles of the four fish species did not exceed the daily reference values for adults. The EDI, THQ and TTHQ values did not indicate a risk of a toxic effect on people consuming these four fish species. All examined fish species contained a significant quantity of Cr, and grass carp contained a significant quantity of Se as well.

Keywords: microelements, macroelements, fish, health risk.

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INTRODUCTION

Essential elements, which are necessary for the proper course of vital processes in the body (Ahmed et al. 2016), are classified as macro- or microelements according to their content in the body and the level of the daily requirement. The content of macroelements (Ca, P, Mg, K, Na, Cl and S) in the human body is greater than 0.01% and the daily requirement exceeds 100 mg, whereas the content of microelements, also known as trace elements (Fe, Zn, Cu, Mn, F, I, Se, Cr, Mo, Co, Ni, V, B and Si), in the body is lower than 0.01% and the daily requirement does not exceed 100 mg (Gawęcki, Hryniewiecki 2000). However, they may have adverse effects on the body (Dural et al. 2007, Meche et al. 2010, El-Sadaawy et al. 2013, Kalantzi et al. 2013, Dhanakumar et al. 2015, Ahmed et al. 2016, Chanpiwat et al. 2016). Knowledge of the levels of macro- and microelements in food fish is crucial in terms of both nutrition and health protection.

The objective of the present study was to determine the content of Ca, Mg, Cu, Mn, Zn, Fe, Cr and Se in the muscles of grass carp, bighead carp, Siberian sturgeon and wels catfish, and to compare these values with daily reference values for adults. In addition, the EDI (estimated daily intake), THQ (target hazard quotient), and TTHQ (total target hazard quotient) were determined in order to assess the potential risk of a toxic effect of these elements on consumer health.

MATERIAL AND METHODS

Sampling

The fish for the study, i.e. grass carp (*Ctenopharyngodon idella*), n = 12, bighead carp (*Aristichthys nobilis*), n = 12, Siberian sturgeon (*Acipenser baerii*), n = 12 and wels catfish (*Silurus glanis*), n = 12, were obtained from fish farms located in eastern Poland (an agricultural region). The fish were collected in winter. The fish had not received any artificial feed. Directly after they were caught, the fish were killed and transported to the laboratory in boxes at a temp. of 0-4°C. The mean body weight and length of the fish were 2.04±0.55 kg and 54.92±5.58 cm for grass carp, 2.64±0.30 kg and 50.38±1.58 cm for bighead carp, 2.17±0.68 kg and 80.17±7.40 cm for Siberian sturgeon, and 2.68±0.38 kg and 74±3.72 cm for wels catfish. After gutting, the fish were divided with a ceramic knife into two fillets. A sample (about 25 g from both fillets) of dorsal muscles from each fish was taken and homogenized with a vibrating ball mill to obtain a representative sample. Homogenized samples from each individual were stored in marked polyethylene vessels in the laboratory freezer at -20°C until analysis.

Chemical analyses

Triplicate subsamples (5.0 g wet weight sample) were mineralized in an electric furnace at a final temp. of 450°C. The ash was dissolved in 1 M nitric acid and made up to the mark to 25 mL. To verify the method, Fish Protein Certified Reference Material for Trace Metals (CRM, DORM-3) supplied from the National Research Council of Canada (CNRC) was subjected to the same analytical procedure and tested for accuracy. The content of Ca, Mg, Zn and Fe was determined by flame atomic absorption spectrometry (Avanta PM, GBC, Australia) at 422.7 nm, 285.2 nm, 213.9 nm, 248.3 nm, respectively (Tüzen 2003). Measurements of Ca and Mg concentrations were performed in the presence of a lanthanum buffer (Fisher Scientific). The content of Cu, Mn, Cr and Se was determined by atomic absorption spectrometry with electrothermal atomization (GFAAS) and Zeeman background correction (SpektrAA 220Z, Varian, Australia) at 327.4 nm, 279.5 nm, 357.9 nm, and 196.0 nm, respectively (Cui et al. 2010). Sensitivity (characteristic mass), defined as the concentration (mass) of the element giving an absorbance of 0.0044, was as follows: Ca – 0.03 μg ml^{-1}, Mg – 0.004 μg ml^{-1}, Zn – 0.012 μg ml^{-1}, Fe – 0.05 μg ml^{-1}, Cu – 2.6 pg, Mn – 1.2 pg, Cr – 3.2 pg, and Se – 18.2 pg. A palladium nitrate solution (Merck) was used as a chemical modifier for the determination of Se.

All measurements were carried out in triplicate for each sample. Recoveries in the range of 90 - 110% were accepted to validate the analytical procedure for the elements. The limits of detection obtained were 0.029, 0.014, 0.009 and 0.067 μg g^{-1} for Ca, Mg, Zn and Fe, respectively. The limits of detection for Cu, Mn, Cr and Se were 0.008, 0.009, 0.001 and 0.008 μg g^{-1}, respectively. The results were expressed as mg kg^{-1} wet weight (WW).

Health risk assessment

The human health risk from fish consumption was estimated for each element using the following equations (Heshmati et al. 2017):

$$\mathrm{EDI} = \frac{Cm \cdot dc_{fish}}{bw},$$

$$\mathrm{THQ} = \frac{\mathrm{EDI}}{RfD},$$

$$\mathrm{TTHQ} = \mathrm{THQ\ (Cu)} + \mathrm{THQ\ (Mn)} + \mathrm{THQ\ (Zn)} + \mathrm{THQ\ (Fe)} + \mathrm{THQ\ (Cr)} + \mathrm{THQ\ (Se)},$$

where EDI is the estimated daily intake (μg kg^{-1} per day), *Cm* is the mean concentration of elements in the fish muscle (μg g^{-1} = mg kg^{-1}), dc_{fish} is the daily per capita consumption of freshwater fish in Poland (5.47 g per capita per day; www.fao.org/faostat/en/#data/CL), and *bw* is the average adult human body weight (70 kg). THQ is the target hazard quotient, TTHQ is the total target hazard quotient, and *RfD* is the reference dose (mg kg^{-1} per day) established by the United States Environmental Protection Agency – Regional Screening Level, Summary Table (USEPA 2016).

Statistical analysis

Statistical analysis of the data was performed using Statistica software (version 13.1). All data are presented as means and ± SD. Mean values for the elements between fish species were compared by one-way ANOVA or the Kruskal-Wallis test (depending on whether the assumptions of analysis of variance were met). Multiple comparisons were made by post hoc Tukey's or Dunn's test. A p value < 0.05 was considered statistically significant for all comparisons.

RESULTS AND DISCUSSION

The content of Ca, Mg, Cu, Mn, Zn, Fe, Cr and Se in the muscles of grass carp, bighead carp, Siberian sturgeon and wels catfish are presented in Table 1.

Calcium (Ca) was the most abundant element in the muscles of grass carp, bighead carp and wels catfish and the second most abundant in the muscles of Siberian sturgeon. The average Ca content in the four examined fish species ranged from 68.02 to 894.9 mg kg^{-1} WW. The muscles of the herbivorous species, i.e. grass carp and bighead carp, contained significantly more Ca ($p < 0.05$) than those of the predatory species, i.e. S. sturgeon and wels catfish. As compared to the grass carp and bighead carp, lower Ca content (90-317 mg kg^{-1} WW) has been found in the muscle tissues of salmon, rainbow trout and carp purchased in Poland (Łuczyńska et al. 2011). Higher Ca content than in the wels catfish and S. sturgeon in the present study has been detected in farmed rainbow trout (335 mg kg^{-1} WW) from the Pomeranian Voivodeship in Poland (Barszcz et al. 2014) and in aquacultured sea bream and sea bass (192 and 636 mg kg^{-1} WW, respectively) from a Turkish fish farm in the Aegean Sea (Erkan, Özden 2007). The highest Ca content, however, was noted in the herbivorous species in the present study.

Magnesium (Mg) was the second most abundant element in the muscles of grass carp, bighead carp and wels catfish, and the most abundant in the muscles of Siberian sturgeon. The average content of Mg in the muscles of the fish species ranged from 97.60 to 226.0 mg kg^{-1} WW. Significantly more Mg ($p < 0.05$) was noted in the muscles of (in decreasing order) grass carp, bighead carp and Siberian sturgeon than in the muscles of wels catfish, and significantly more in the muscles of grass carp than in S. sturgeon. As compared to the results of the current study, higher levels of Mg have been found in the muscles of other farmed fish species, such as rainbow trout (312 mg kg^{-1} WW) from Poland (Barszcz et al. 2014) or sea bass (326 mg kg^{-1} WW) from a Turkish fish farm in the Aegean Sea (Erkan, Özden 2007), as well as in migratory fish species, such as *Liza ramada*, *Liza aurata*, *Mugil cephalus*, *Lithognathus mormyrus*, *Chelon labrasus* and *Sparus aurata* (262.53-332.56 mg kg^{-1} WW) from the Beymelek Lagoon, Antalya, Turkey (Uysal et al. 2008).

Table 1

Content of elements in the muscles of the fish species (mg kg^{-1} WW)

Elements	Fish species											
	grass carp (n = 12)			bighead carp (n = 12)			Siberian sturgeon (n = 12)			wels catfish (n = 12)		
	mean	SD	range	mean	SD	range	mean	SD	range	mean	SD	range
Ca	894.9^{a}	274.3	615.6-1485	820.5^{a}	552.9	264.8-2173	68.02^{b}	29.85	46.14-151.4	141.34^{b}	127.8	64.76-299.3
Mg	226.0^{a}	26.36	186.4-268.8	189.0^{ab}	33.19	142.2-250	165.9^{b}	15.67	147-198.6	97.60^{c}	12.63	67.8-112.8
Cu	0.36^{b}	0.08	0.206-0.481	0.66^{a}	0.15	0.385-0.906	1.15^{a}	0.33	0.54-1.57	0.79^{a}	0.33	0.432-1.657
Mn	0.25^{a}	0.11	0.139-0.403	0.34^{a}	0.13	0.192-0.563	0.26^{a}	0.03	0.2-0.341	0.28^{a}	0.08	0.179-0.418
Zn	6.13^{ac}	1.39	3.868-9.064	6.59^{ac}	0.75	5.268-7.908	5.78^{bc}	0.85	4.824-7.356	7.09^{ad}	1.44	4.8-9.132
Fe	4.29^{a}	1.32	1.412-6.332	6.73^{a}	3.50	3.076-13.68	6.63^{a}	2.38	2.616-11.59	5.78^{a}	3.15	2.784-11.99
Cr	0.08^{b}	0.09	0.025-0.335	0.33^{a}	0.358	0.007-1.089	0.13^{ab}	0.23	0.02-0.84	0.29^{ab}	0.36	0.037-1.023
Se	0.02^{b}	0.00	0.013-0.023	0.03^{a}	0.012	0.019-0.053	0.05^{a}	0.01	0.025-0.079	0.04^{a}	0.01	0.026-0.059

SD – standard deviation, ^{a,b,c,d} means in the same row with different superscript letters are significantly different $p < 0.05$, n – number of fish, WW – wet weight

The average copper (Cu) content in the muscles of the four fish species was 0.36-1.15 mg kg^{-1} WW. Levels of Cu ($p < 0.05$) were significantly lower in grass carp than in bighead carp, wels catfish, and S. sturgeon, in which the Cu content was comparable. In comparison with these results, higher Cu content has been reported in the muscles of *Glossogobius giuris*, *Puntius chola*, *Puntius sophore*, *Puntius ticto* and *Labeo rohita* (5.90-18.77 mg kg^{-1} WW) from the Buriganga River in Bangladesh (Ahmed et al. 2016). Much lower Cu levels (mg kg^{-1} WW) have been noted in the muscles of cultured freshwater fish from Jiangxi Province, China, such as mandarin fish (0.089), northern snakehead (0.13) and silver carp (0.18) (Zhang et al. 2014), while copper content in *Channa striata* was below the detection limit (Dhanakumar et al. 2015).

The mean manganese (Mn) content in the muscles of the four fish species was comparable (no statistically significant differences), and amounted to 0.25-0.34 mg kg^{-1} WW. Lower content of Mn has been reported in the muscle tissues of rainbow trout and carp (0.072 and 0.150 mg kg^{-1} WW, respectively) from Poland (Łuczyńska et al. 2011) and in *Lethrinus* sp., *Nemipterus japonicus*, *Epinephelus* sp. and *Trachurus mediterraneus* (0.10, 0.11, 0.16 and 0.18 μg g^{-1} WW, respectively) from Suez, the Red Sea, Egypt (El-Moselhy et al. 2014). Dhanakumar et al. (2015) reported that the Mn concentration in *Channa striata*, *Mystus vittatus* and *Cirrhinus mrigala* from India was below the detection limit. In comparison with the four species examined in this study, Mn content was higher in the muscles of *Sparus aurata* and *Oreochromis niloticus* (0.376 and 0.386 μg g^{-1} WW, respectively) from the Gaza Strip, Palestine (Elnabris et al. 2013) and in *P. sophore*, *G. giuris*, *P. chola*, *P. ticto* and *L. rohita* (22.42-125.81 mg kg^{-1} WW) from the Buriganga River in Bangladesh (Ahmed et al. 2016).

The mean zinc (Zn) content in the muscles of the presented fish species was 5.78-7.09 mg kg^{-1} WW. Significant differences in Zn content ($p < 0.05$) were noted between two species, with a higher level found in wels catfish than in the S. sturgeon. Compared with the results in this study, higher concentrations of Zn have been noted in the muscle of mangrove snapper, star snapper, snubnose pompano, mandarin fish, black bass, snakehead and tilapia from China (15.2-29.5 mg kg^{-1} WW) (Leung et al. 2014) and in *Odontesthes bonariensis* from Argentina (12.0-18.4 mg kg^{-1} WW) (Avigliano et al. 2015). Lower mean content of Zn than in the four fish species included in this study has been found in the muscles of salmon, rainbow trout and carp purchased in Poland (3.35, 4.27 and 5.15 mg kg^{-1} WW, respectively) (Łuczyńska et al. (2011); bream from lakes Ińsko and Wisola in Poland (3.2 and 3.0 μg g^{-1} WW, respectively) (Rajkowska, Protasowicki 2013); and sea bass and sea bream (2.833 and 1.081 mg kg^{-1} WW, respectively) from a Turkish fish farm, the Aegean Sea (Erkan, Özden 2007).

Mean content of iron (Fe) in the muscle tissues of the four analysed fish species was 4.29-6.73 mg kg^{-1} WW. However, the Fe levels did not differ significantly among these fish species ($p > 0.05$). Compared with the Fe content of the presented fish species, lower Fe content (mg kg^{-1} WW) has been noted in the muscles of salmon (1.46), rainbow trout (1.55) and carp (2.31) (Łuczyńska et al. 2011) and in pike and bream (0.8-1.5) from Poland (Rajkowska, Protasowicki 2013). Higher levels of Fe (mg kg^{-1} WW) have been found in the muscles of tench (31.2-112.9), pike-perch (26.1-414.5) and common carp (14.9-73.4) from Turkey (Mert et al. 2014).

The average chromium (Cr) content in the muscles of the examined fish species was 0.08-0.33 mg kg^{-1} WW. Significant differences in Cr content ($p < 0.05$) were found between the herbivorous species, with the grass carp muscles containing less Cr than bighead carp. Cr content ranged from 0.059 to 0.068 mg kg^{-1} WW in the muscles of farmed fish from Beijing, i.e. *Oncorhynchus mykiss*, *Cyprinus carpio* and *Ctenopharyngodon idella* (Jiang et al. 2016); from 0.10 to 0.239 mg kg^{-1} WW in the muscles of fish from the Yangtze River, i.e. *Pelteobagrus fulvidraco*, *Coreius heterodom*, *Carassius auratus*, *Hypophthalmichthys molitrix*, *Silurus asotus* and *Cyprinus carpio* (Yi, Zhang 2012); and from 0.0526 to 1.1438 mg kg^{-1} WW in the muscles of freshwater fish from Turkey, i.e. common carp, pike-perch and tench (Mert et al. 2014). In current study, the Cr content in the muscles of the four fish species was within these ranges. Uysal et al. (2008) reported that Cr was not detected in the muscles of 5 fish species from the Beymelek Lagoon (Antalya, Turkey), i.e. *L. ramada*, *L. aurata*, *L. mormyrus*, *C. labrasus* and *S. aurata*.

The mean content of selenium (Se) in the muscles of the four examined fish species was 0.02-0.05 mg kg^{-1} WW. Significantly more Se ($p < 0.05$) was found in the muscles of (in decreasing order) the Siberian sturgeon, wels catfish and bighead carp than in the grass carp. Markedly more Se than in these four fish species was observed in the muscles of tropical fish from the Buriganga River in Bangladesh, i.e. *Gagata youssoufi*, *Mastacembelus pancalus* and *Ailia coila* (1.46-1.99 mg kg^{-1} WW) (Ahmed et al. 2015); in *P. sophore*, *P. chola*, *L. rohita*, *P. ticto* and *G. giuris* collected from the Buriganga River in Bangladesh (1.68-1.98 mg kg^{-1} WW) (Ahmed et al. 2016); and in *Odontesthes bonariensis* from various environments in Argentina (0.41-5.28 mg kg^{-1} WW) (Avigliano et al. 2015). Lower Se levels than in the four examined species have been reported in some individuals of grass carp species (0.0048-0.18 mg kg^{-1} WW) from Jiangxi Province, China (Zhang et al. 2014). Se was not detectable in the muscles of 9 of 16 analysed fish species from the Piracicaba River in southern Brazil (Meche et al. 2010).

The data presented indicate differences in the content of elements in the muscles of fish. These differences may result from the species of fish, the season or the geographical region (Łuczyńska et al. 2011, Mert et al. 2014, Leung et al. 2014, Avigliano et al. 2015).

The daily reference intakes of minerals (macro- and micronutrients) for adults according to Regulation (EU) No 1169/2011 are 800 mg for Ca, 375 mg for Mg, 1 mg for Cu, 2 mg for Mn, 10 mg for Zn, 14 mg for Fe, 55 μg for Se and 40 µg for Cr. Assuming that consumption of freshwater fish in Poland is 5.47 g per person per day (www.fao.org/faostat/en/#data/CL), the content of each of the macro- and microelements examined (except Cr) in the grass carp, bighead carp, Siberian sturgeon and wels catfish was less than 1% of the daily reference intake for an adults. Cr content was 12.50% of the daily reference intake in grass carp, 20% in Siberian sturgeon, and 50% in bighead carp and wels catfish. Therefore, the content of macro- and microelements in the muscles of these fish species did not exceed the daily reference values for adults. If the content of a macro- or microelement reaches at least 15% of the reference values in 100 g of product, it is defined as a significant quantity (Regulation EU No 1169/2011). In 100 g of fish muscles, the percentages of the daily reference intakes of elements were as follows: grass carp Ca 11.2%, Mg 6%, Cu 3.6%, Mn 1.25%, Zn 6%, Fe 3%, Se 36% and Cr 200%; bighead carp Ca 10.26%, Mg 5.04%, Cu 6.6%, Mn 1.7%, Zn 6.59%, Fe 4.81%, Se 5.45% and Cr 825%; Siberian sturgeon Ca 0.85%, Mg 4.43%, Cu 11.5%, Mn 1.3%, Zn 5.78%, Fe 4.74%, Se 9.09% and Cr 325%; and wels catfish Ca 1.76%, Mg 2.60%, Cu 7.9%, Mn 1.4%, Zn 7.09%, Fe 4.13%, Se 7.27% and Cr 725%. Therefore, the quantity of Cr in all examined fish species and of Se in grass carp was significant. The content of the other elements was below 15% of the reference values in 100 g of product.

In fish from Greece, the content of P, Ca and Se exceeded 100% of the recommended daily allowances. In flathead grey mullet, the content of P and Ca was 165% and 225% of the recommended doses, respectively, while in picarel and comber the Se levels were 102% and 112% of the recommended doses, respectively (Kalantzi et al. 2013).

The EDI (estimated daily intake), THQ (target hazard quotient) and TTHQ (total target hazard quotient) calculated for individual elements through consumption of muscles of the grass carp, bighead carp, Siberian sturgeon and wels catfish are presented in Table 2. The quantity of elements supplied to the body with food depends on both their content in the food and the amount of food consumed. The estimated EDI values were based on the assumption that a person weighing 70 kg will consume 5.47 g of fish per day. The results showed that the EDI values were lower than the reference dose (RfD) values defined by the USEPA (2016), indicating that there was no health risk associated with the intake of the elements tested through the consumption of the grass carp, bighead carp, Siberian sturgeon and wels catfish analysed in the current study. The acceptable value for THQ and TTHQ is 1 (USEPA 2016). The THQ and TTHQ values were less than 1, which means that the elements Cu, Mn, Zn, Fe, Cr and Se posed no threat to the health of consumers of these four fish species, either individually (THQ) or in combination (TTHQ). Similarly, THQ values were less than 1 for Cr in the muscles of the commercial fish species *Engraulis encrasicolus*, *Sardina pilchardus* and *Mullus barbatus* from various Sicilian areas (Copat et al. 2012). In contrast, hazard quotients were many times higher than the ac-

Table 2

Estimated daily intakes (EDI) of elements via consumption of fish and hazard quotients (THQ and TTHQ)

Fish species and trace elements	Average concentration (μg g^{-1})	EDI estimated daily intakes (μg kg^{-1} per day)	RfD reference dose (μg kg^{-1} per day)	THQ target hazard quotient and TTHQ total target hazard quotient
Grass carp (n = 12)				
Ca	894.93	69.93 E-00	-	-
Mg	226.00	17.66 E-00	-	-
Cu	0.36	2.8 E-02	40	7 E-04
Mn	0.25	2.0 E-02	140	1.43 E-04
Zn	6.13	4.8 E-01	300	1.6 E-03
Fe	4.29	3.4 E-01	700	4.79 E-04
Cr	0.08	6.3 E-03	1500	0.42 E-05
Se	0.02	1.6 E-03	5	3.2 E-04
				TTHQ = 3.25 E-03
Bighead carp (n = 12)				
Ca	820.50	64.12 E-00	-	-
Mg	189.00	14.77 E-00	-	-
Cu	0.66	5.2 E-02	40	1.3 E-03
Mn	0.34	2.7 E-02	140	19.3 E-05
Zn	6.59	5.2 E-01	300	17.33 E-04
Fe	6.73	5.3 E-01	700	75.2 E-05
Cr	0.33	2.6 E-02	1500	17.2 E-06
Se	0.03	2.4 E-03	5	4.8 E-04
				TTHQ = 4.48 E-0.3
Siberian sturgeon (n = 12)				
Ca	68.02	5.32 E-00	-	-
Mg	165.85	12.96 E-00	-	-
Cu	1.15	9.0 E-02	40	22.5 E-04
Mn	0.26	2.0 E-02	140	14.3 E-04
Zn	5.78	4.5 E-01	300	1.5 E-03
Fe	6.63	5.2 E-01	700	7.4 E-03
Cr	0.13	1.0 E-02	1500	6.7 E-05
Se	0.05	3.9 E-03	5	7.8 E-03
				TTHQ = 20.45 E-0.3
Wels catfish (n = 12)				
Ca	141.34	11.04 E-00	-	-
Mg	97.60	7.63 E-00	-	-
Cu	0.79	6.2 E-02	40	15.5 E-04
Mn	0.28	2.2 E-02	140	15.7 E-05
Zn	7.09	5.5 E-01	300	18.33 E-04
Fe	5.78	4.5 E-01	700	64.4 E-04
Cr	0.29	2.3 E-02	1500	15.4 E-05
Se	0.04	3.2 E-03	5	6.4 E-03
				TTHQ = 16.53 E-0.3

(-) no data RfD for Ca and Mg

n – number of fish

ceptable value of 1 for Cu and Zn in catfish, climbing fish, common carp and snapper from Vietnam (the Mekong River) (Chanpiwat et al. 2016). Levels of Cr and Co (4.05 and 1.74, respectively) in the muscles of freshwater Nile tilapia (*Oreachromis niloticus* Linnaeus, 1758) from Egypt also exceeded the acceptable value for the hazard quotient (El-Sadaawy et al. 2013). The THQ values for individual heavy metals (V, Cr, Mn, Ni, Cu, Zn, As, Se, Mo, Ag, Cd, Sb, Ba and Pb) were below 1, but their combined impact estimated by TTHQ suggested a health risk associated with consumption of *M. pancalus* from the Buriganga River in Bangladesh (Ahmed et al. 2015).

CONCLUSION

The content of macroelements and microelements (Ca, Mg, Cu, Mn, Zn, Fe, Cr and Se) in the muscles of grass carp, bighead carp, Siberian sturgeon and wels catfish did not exceed the daily reference values for adults. The EDI, THQ and TTHQ values did not indicate a risk of a toxic effect of these elements on people consuming these fish species.

The quantity of the chromium (Cr) in the muscles of grass carp, bighead carp, Siberian sturgeon and wels catfish and that of selenium (Se) in the muscles of grass carp was determined to be significant.

REFERENCES

Ahmed M.K., Baki M.A., Islam M.S., Kundu G.K., Habibullah-Al-Mamun M., Sarkar S.K., Hossain M.M. 2015. *Human health risk assessment of heavy metals in tropical fish and shellfish collected from the river Buriganga, Bangladesh*. Environ. Sci. Pollut. Res., 22(20): 15880-15890.

Ahmed M.K., Baki M.A., Kundu G.K., Islam M.S., Islam M.M., Hossain M.M. 2016. *Human health risks from heavy metals in fish of Buriganga river, Bangladesh*. SpringerPlus, 5(1):1697.

Avigliano E., Schenone N.F., Volpedo A.V., Goessler W., Cirelli A.F. 2015. *Heavy metals and trace elements in muscle of silverside (Odontesthes bonariensis) and water from different environments (Argentina): aquatic pollution and consumption effect approach*. Sci. Total Environ., 506-507: 102-108.

Barszcz A.A., Sidoruk M., Siemanowska E., Skibniewska K.A., Szarek J. 2014. *Bioaccumulation of minerals in muscle tissue of rainbow trout in dependence on breeding conditions*. Proc. ECOpole, 8(2): 471-480.

Chanpiwat P., Sthiannopkao S., Widmer K., Himeno S., Miyataka H., Vu N.U., Tran V.V., Pham T.T. 2016. *Assessment of metal and bacterial contamination in cultivated fish and impact on human health for residents living in the Mekong Delta*. Chemosphere, 163: 342-350.

Copat C., Bella F., Castaing M., Fallico R., Sciacca S., Ferrante M. 2012. *Heavy metals concentrations in fish from Sicily (Mediterranean Sea) and evaluation of possible health risks to consumers*. Bull. Environ. Contam. Toxicol., 88(1): 78-83.

Cui X., Wang Y., She X. 2010. *Determination of Ca, K, Mg and Fe in four fish species by FAAS*. J. Ocean Univ. China, 9(3): 235-238.

Dhanakumar S., Solaraj G., Mohanraj R. 2015. *Heavy metal partitioning in sediments and bioaccumulation in commercial fish species of three major reservoirs of river Cauvery delta region, India*. Ecotoxicol. Environ. Saf., 113: 145-151.

Dural M., Göksu M.Z.L., Özak A.A. 2007. *Investigation of heavy metal levels in economically important fish species captured from the Tuzla lagoon*. Food Chem., 102(1): 415-421.

El-Moselhy Kh.M., Othman A.I., Abd El-Azem H., El-Metwally M.E.A. 2014. *Bioaccumulation of heavy metals in some tissues of fish in the Red Sea, Egypt*. Egypt. J. Basic Appl. Sci., 1(2): 97-105.

El-Sadaawy M.M., El-Said G.F., Sallam N.A. 2013. *Bioavailability of heavy metals in fresh water Tilapia nilotica (Oreachromis niloticus* Linnaeus*, 1758): Potential risk to fishermen and consumers*. J. Environ. Sci. Health B, 48(5): 402-409.

Elnabris K.J., Muzyed S.K., El-Ashgar N.M. 2013. *Heavy metal concentrations in some commercially important fishes and their contribution to heavy metals exposure in Palestinian people of Gaza Strip (Palestine)*. J. Assn. Arab. Univ. Basic. Appl. Sci., 13(1): 44-51.

Erkan N., Özden Ö. 2007. *Proximate composition and mineral contents in aqua cultured sea bass (Dicentrarchus labrax), sea bream (Spartus aurata) analyzed by ICP-MS*. Food Chem., 102(3): 721-725.

Gawęcki J., Hryniewiecki L. 2000. *Human Nutrition. Foundations of Food Science*. PWN, Warszawa. (in Polish)

Heshmati A., Karami-Momtaz J., Nili-Ahmadabadi A., Ghadimi S. 2017. *Dietary exposure to toxic and essential trace elements by consumption of wild and farmed carp (Cyprinus carpio) and Caspian kutum (Rutilus frisii kutum) in Iran*. Chemosphere, 173: 207-215.

Jiang H., Qin D., Mou Z., Zhao J., Tang S., Wu S., Gao L. 2016. *Trace elements in farmed fish (Cyprinus carpio, Ctenopharyngodon idella and Oncorhynchus mykiss) from Beijing: implication from feed*. Food Addit. Contam. Part B, 9(2): 132-141.

Kalantzi I., Black K.D., Pergantis S.A., Shimmield T.M., Papageorgiou N., Sevastou K., Karakassis I. 2013. *Metals and other elements in tissues of wild fish from fish farms and comparison with farmed species in sites with oxic and anoxic sediments*. Food Chem., 141(2): 680-694.

Leung H.M., Leung A.O.W., Wang H.S., Ma K.K., Liang Y., Ho K.C., Cheung K.C., Tohidi F., Yung K.K.L. 2014. *Assessment of heavy metals/metalloid (As, Pb, Cd, Ni, Zn, Cr, Cu, Mn) concentrations in edible fish species tissue in the Pearl River Delta (PRD) China*. Mar. Pollut. Bull., 78(1-2): 235-245.

Łuczyńska J., Tońska E., Borejszo Z. 2011. *Content of macro- and microelements, and fatty acids in muscles of salmon (Salmo salar* L.*), rainbow trout (Oncorhynchus mykiss* Walb.*), and carp (Cyprinus carpio* L.*)*. Żywność. Nauka. Technologia. Jakość, 76(3): 162-172.

Meche A., Martins M.C., Lofrano B.E.S.N., Hardaway C.J., Merchant M., Verdade L. 2010. *Determination of heavy metals by inductively coupled plasma-optical emission spectrometry in fish from the Piracicaba River in Southern Brazil*. Microchem. J., 94(2): 171-174.

Mert R., Alaş A., Bulut S., Özcan M.M. 2014. *Determination of heavy metal contents in some freshwater fishes*. Environ. Monit. Assess., 186(11): 8017-8022.

Rajkowska M., Protasowicki M. 2013. *Distribution of metals (Fe, Mn, Zn, Cu) in fish tissues in two lakes of different trophy in Northwestern Poland*. Environ. Monit. Assess., 185(4): 3493-3502.

Regulation (EU) No 1169/2011 of the European Parliament and of the Council of 25 October 2011 *on the provision of food information to consumers, amending Regulations (EC) No 1924/2006 and (EC) No 1925/2006 of the European Parliament and of the Council, and repealing Commission Directive 87/250/EEC, Council Directive 90/496/EEC, Commission Directive 1999/10/EC, Directive 2000/13/EC of the European Parliament and of the Council, Commission Directives 2002/67/EC and 2008/5/EC and Commission Regulation (EC) No 608/2004.*

Tüzen M. 2003. *Determination of heavy metals in fish samples of the middle Black Sea (Turkey) by graphite furnace atomic absorption spectrometry. Food Chem.,* 80(1): 119-123.

USEPA. 2016. *Regional Screening Level (RSL).* Summary Table.

Uysal K., Emre Y., Köse E. 2008. *The determination of heavy metal accumulation ratios in muscle, skin and gills of some migratory fish species by inductively coupled plasma-optical emission spectrometry (ICP-OES) in Beymelek Lagoon (Antalya/Turkey).* Microchem. J., 90(1): 67-70.

Yi Y.J., Zhang S.H. 2012. *The relationships between fish heavy metal concentrations and fish size in the upper and middle reach of Yangtze River.* Procedia Environ. Sci., 13:1699-1707.

Zhang L., Zhang D., Wei Y., Luo L., Dai T. 2014. *Risk assessment of trace elements in cultured freswather fishes from Jiangxi province, China.* Environ. Monit. Assess., 186(4): 2185-2194.

Conflict of interest

The authors declare that they have no conflict of interest.

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