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# CONTENT OF MACROMINERALS AND TRACE ELEMENTS IN THE MEAT OF CARP GROWN IN DIFFERENT PRODUCTION SYSTEMS

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## Abstract

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The purpose of the present study was to investigate the content of macrominerals and trace elements in the meat of carp, reared in different production systems. The experiments for fatty acids content of lipids were carried out in 2012-2013 in common carp (*Cyprinus carpio* L.) for human consumption reared in production systems with various level of intensification (semi-intensive, intensive, super-intensive) and farming techniques (earth ponds, dam lakes, net cages). The content of the primary macrominerals and trace elements in carp meat and its specificity related to the used production system has been established. It was demonstrated that the prevailing macrominerals were the potassium (2713.86 – 3552.22 mg.kg$^{-1}$) and the phosphorus (2261.18 – 2417.86 mg.kg$^{-1}$). Out of the studied trace elements, carp meat had a higher content of iron (4.43 – 7.14 mg.kg$^{-1}$) and zinc (2.22 – 8.88 mg.kg$^{-1}$). The results from this study could be used as objective information for evaluation of the nutritional value of carp meat with regard to the content of macrominerals and trace elements.

*Key words:* carp, *Cyprinus carpio* L., meat, mineral composition, macro elements, trace elements

## Introduction

Fish meat is a valuable source of important macro– and trace elements. The mineral content is species-specific and could vary according to the season. According to Hakanson (1984) the content of macro– and trace elements in fish muscle tissue is self-regulated and depends on the habitat, environmental conditions (Buchtová and Ježek, 2011), fish species (Łuczyńska et al., 2006), the gender, age and feeding type (Gladyshev et al., 2001; Atanasoff et al., 2013). The analysis of the mineral content of carp, European catfish and pike perch meat performed by Ozyurt et al. (2009) reported sodium concentrations between 61.25–130.10 mg.100 g$^{-1}$; potassium: 305.90–358.10 mg.100 g$^{-1}$; magnesium: 27.11–37.43 mg.100 g$^{-1}$; manganese: 0.85–1.36 mg.100 g$^{-1}$; copper: 0.08–0.13 mg.100 g$^{-1}$; and zinc: 1.25–1.32 mg.100 g$^{-1}$.

Among macroelements, phosphorus, magnesium and calcium are structural components participating in the buildup of bone and other tissues, hence they are essential for human health. Potassium and sodium are involved in the regulation of water content of tissues as well as blood and tissue acid-base balance (Brzozowska, 2000).

Trace elements – iron, zinc, copper and manganese are also essential for human health. Their deficiency or excess could provoke chronic diseases (Przyby and Koligot, 1997; ATSDR, 2004; Demirezen, 2006). Iron, copper and zinc are heavy metals (Güner et al., 1998). Their toxic effects depend on the site of accumulation in the body (Jezierska and Witeska, 2001). In fish, they are mainly accumulated in the kidneys, liver, intestines and in small amounts, in other organs too (Protasowicki, 1987). Having investigated the content of macro- and trace elements in fish meat, Witeska and Jezierska (2001) established lower concentrations in muscle tissue compared to levels of other organs.

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The purpose of the present study was to investigate the content of macrominerals and trace elements in the meat of carp, reared in different production systems.

## Materials and Methods

The experiments for the content of macrominerals and trace elements were carried out in 2012–2013 in common carp (*Cyprinus carpio* L.) for consumption reared in production systems with various level of intensification (semi-intensive, intensive, super-intensive) and farming techniques (earth ponds, dam lakes, net cages). Semi-intensive systems (SemiIS) were as followed: The Tri Voditsi/ 10 Experimental base (SemiIS-1), and Tsarimir 1 dam lake (SemiIS-2). Intensive systems (IS) were the Tundzha 73/ 4 fish farm (IS-1), the Tundzha 73/ 5 fish farm (IS-2), and Tsarimir 2 Dam Lake (IS-3). Super-intensive systems consisted of net cages in Kardzhali Dam Lake (SuperIS-1) The 40 Izvora Dam Lake was used as control aquatic ecosystem (CAES) (Table 1).

Once monthly, from May to October for each year of the study, analysis of physico-chemical parameters of water in experimental ponds was performed. The obtained values for water temperature, water pH and dissolved oxygen were within the technological allowances for cyprinids providing adequate farming conditions.

The samples of fish for the purposes of the study were randomly selected from each production system. Individual samples for analysis were obtained from fish musculature (lateral muscle) at the same site, after removal of the skin with subcutaneous fat and grinding and homogenization of meat. The analysis of macro and trace elements was done by atomic absorption spectrophotometry (AOAC, 2007). The meat samples were submitted to chemical digestion and evaporation using MULTIWAVE 3000, Perkin Elmer. The quantization was done with ANALYST 800 AA SPEKTROMETER, Perkin Elmer, with flame/graphite furnace and additional flow injection hydride system. Assayed macroelements were phosphorus, magnesium, potassium, sodium and calcium, and trace elements – iron, copper and zinc.

The statistical analysis of data was done with the MS Office 2010 software. The significance of differences between two samples was evaluated with the Student's t-test at a level of significance $P < 0.05$.

## Results and Discussion

***Macrominerals***

The content of some essential macrominerals in the meat of carps reared in studied production systems are presented in Table 2.

Average values of meat phosphorus (P) varied from 2261.18 mg.kg$^{-1}$ to 2417.86 mg.kg$^{-1}$. In general, the concentrations of this element were not significantly different among studied production systems and variations ranged within 6–7% ($P > 0.05$). According to ordinance 23 of the Ministry of Health (2005) the recommended daily dietary P intake for men and women is 700–1250 mg and one serving (300 g fish) from studied carp groups could satisfy the daily needs of adults.

Magnesium (Mg) content varied from 299.35 to 369.48 mg.kg$^{-1}$. In carps reared in the net cages of the Kardzhali Dam Lake, Mg level (369.48 mg.kg$^{-1}$) was statistically significantly higher than that in the other studied groups ($P < 0.01$; $P < 0.001$) except for fish reared in SemiIS-1 – The Tri Voditsi /10 experimental base ($P > 0.05$). Minimum average Mg concentrations were detected in the group from the Tundzha 73 /5 fish farm (299.35 mg.kg$^{-1}$), which were considerably lower than respective values in carps from the net cages ($P < 0.001$) and the semi-intensive Tri Voditsi /10 farm ($P < 0.05$).

**Table 1**

**Characteristics of the studied production systems**

| Production systems | Semi-intensive | | Intensive | | | Super-intensive | Control aquatic ecosystem |
|---|---|---|---|---|---|---|---|
| | SemiIS-1* | SemiIS-2 | IS-1 | IS-2 | IS-3 | Super IS-1 | CAES |
| Type of feed | grain / meal | grain / meal +CEF** | CPF | CEF | CEF | CEF | for angling |
| Ratio of feed, % | 50:50 | 73:16:11 | 100 | 100 | 100 | 100 | – |
| area | | | | | | | |
| da | 45 | 500 | 750 | 200 | 40 | – | 489 |
| m$^3$ | – | – | – | – | – | 156 | – |

*(SemiIS-1) – Tri Voditsi/ 10 Experimental base; (SemiIS-2) – Tsarimir 1 dam lake; (IS-1) – Tundzha 73/ 4 fish farm; (IS-2) – Tundzha 73/ 5 fish farm; (IS-3) – Tsarimir 2 dam lake; (SuperIS-1) – net cages in Kardzhali dam lake; (CAES) – the 40 Izvora dam lake

***CEF – combined extruded feed; CPF – combined pelleted feed*

**Table 2**

**Content of macrominerals in the meat of carp reared in different production systems**

| Production systems | P | | Mg | | K | | Na | | Ca | |
|---|---|---|---|---|---|---|---|---|---|---|
| | x | Sx | x | Sx | x | Sx | x | Sx | x | Sx |
| Tri Voditsi/ 10 Experimental base | 2393.72 | 116.71 | 361.83 | 16.68 | 2849.12 | 104.16 | 519.59 | 23.28 | 1088.70 | 272.26 |
| Tsarimir 1 dam lake | 2417.86 | 39.49 | 307.02 | 4.30 | 3504.97 | 96.86 | 637.71 | 21.11 | 341.94 | 39.24 |
| Tundzha 73/ 4 fish farm | 2335.45 | 175.39 | 300.80 | 5.89 | 2803.02 | 87.55 | 517.69 | 18.45 | 496.35 | 64.19 |
| Tundzha 73/ 5 fish farm | 2329.32 | 67.16 | 299.35 | 5.99 | 3552.22 | 97.60 | 569.68 | 14.83 | 328.61 | 41.83 |
| Tsarimir 2 dam lake | 2321.53 | 107.60 | 310.38 | 3.39 | 3357.69 | 57.37 | 486.13 | 17.42 | 383.79 | 123.34 |
| Net cages in the Kardzhali dam lake | 2261.18 | 101.93 | 369.48 | 4.42 | 2713.42 | 213.86 | 533.88 | 73.35 | 1005.50 | 330.39 |
| The 40 Izvora dam lake | 2363.07 | 58.70 | 324.52 | 7.49 | 3406.33 | 76.38 | 344.15 | 15.76 | 286.97 | 14.81 |

The recommended daily intake of magnesium is 250 mg for both genders (Ordinance 23 of the Ministry of Health/2005). One serving of carp from studied groups provides from ½ (half) to ⅓ (one-third) of the needed daily amount. This is of particular significance, as magnesium is an essential macromineral for the functioning of cells playing a key role in all reactions involving phosphates (Pirestani et al., 2009).

The meat potassium (K) concentrations in studied groups of carp varied within the range 2713.86 $mg.kg^{-1}$ – 3552.22 $mg.kg^{-1}$. The muscle tissue of carps from the Tri Voditsi /10 experimental base and Tundzha 73/4 fish farm had statistically significantly lower Mg levels ($P < 0.05$; $P < 0.01$) as compared to the other studied production systems.

With regard to its potassium (K) content, the meat of studied carps provide from one-fourth to one-sixth of the daily allowance (4.7 g, Ordinance 23 of the Ministry of Health/2005). This macromineral is essential for the normal function of nerves, muscles, glucose metabolism, acid-base equilibrium, cerebral oxygen metabolism as well as the cardiac activity (Tolonen, 1990).

The comparison of sodium (Na) content of studied groups of carp meat showed the lowest average values in fish cultured in The 40 Izvora aquatic ecosystem (344.15 $mg.kg^{-1}$) which were statistically significantly lower than Na concentrations in other groups ($P < 0.01$; $P < 0.001$). The maximum value (637.71 $mg.kg^{-1}$) was established in fish from Tsarimir 1 Dam Lake. There were not substantial differences in muscle Na levels of fish reared in the Kardzhali dam intensive system vs the other groups ($P > 0.05$).

According to norms for adequate Na daily intake (1.2 g) as per Ordinance 23 of the Ministry of Health/2005, one serving of fish from studied fish farms provides from 1/11 to 1/6 of the necessary amount of sodium, which is needed for regulation of systemic electrolyte and acid-base balance, muscle contractions, production of adrenaline and amino acids.

Calcium (Ca) concentrations in the meat of studied groups of carps varied within a rather broad range from 286.97 $mg.kg^{-1}$ to 1088.70 $mg.kg^{-1}$. The difference between the lowest and the highest detected concentrations was about 3.8 times. There were statistically significant differences in Ca meat levels between The 40 Izvora aquatic ecosystem vs both the Tri Voditsi /10 experimental vase and Tundzha 73 /4 fish farm ($P < 0.05$).

According to Ordinance 23/2005, the recommended daily calcium intake is 1000–1300 for men and 700–1250 mg for women. Therefore, one serving of carp meat supplies between 1/11 and ⅓ of the needed amount for men and from ⅛ to ½ for women.

The analysis of data indicates that carp meat concentrations of sodium and potassium differed significantly between production systems – from 2 times (Tsarimir 1 Dam Lake) to 4 times (Tri Voditsi /10 experimental base) vs the control ecosystem The 40 Izvora. This support the results reported by Gopakumar (1997), that meat calcium content of fish from the same species could differ significantly. The obtained calcium concentrations of meat (966 $mg.kg^{-1}$) were similar to those demonstrated by Pirestani et al. (2009). The levels of phosphorus, magnesium and sodium (P, Mg, K) in fish from the studied production systems were comparable.

***Trace elements***

The content of several primary trace elements from the mineral content of carp meat produced in different systems is presented in Table 3.

According to the data, average copper (Cu) levels of carp meat varied between 0.83 $mg.kg^{-1}$ (The 40 Izvora Dam Lake) and 1.64 $mg.kg^{-1}$ (net cages of the Kardzhali Dam Lake).

**Table 3**

**Content of trace elements in the meat of carp reared in different production systems**

| Production systems | Cu | | Fe | | Zn | |
|---|---|---|---|---|---|---|
| | x | Sx | x | Sx | x | Sx |
| Tri Voditsi/ 10 Experimental base | 1.35 | 0.12 | 6.58 | 0.67 | 3.80 | 0.49 |
| Tsarimir 1 dam lake | 1.31 | 0.21 | 7.14 | 1.94 | 3.63 | 0.23 |
| Tundzha 73/ 4 fish farm | 1.32 | 0.13 | 5.41 | 0.33 | 2.93 | 0.32 |
| Tundzha 73/ 5 fish farm | 1.14 | 0.05 | 5.19 | 0.56 | 2.22 | 0.38 |
| Tsarimir 2 dam lake | 1.52 | 0.57 | 4.43 | 0.18 | 3.37 | 0.30 |
| Net cages in the Kardzhali dam lake | 1.64 | 0.23 | 5.68 | 0.46 | 8.88 | 0.57 |
| The 40 Izvora dam lake | 0.83 | 0.08 | 5.86 | 0.38 | 2.88 | 0.41 |

In the present study, higher meat iron (Fe) concentrations were established in carps from the semi-intensive production system in the Tsarimir 1 Dam Lake (7.14 mg.kg$^{-1}$) From studied production systems, only the meat of carps from the intensive Tsarimir 2 Dam Lake system had statistically significantly lower Fe levels (4.43 mg.kg$^{-1}$) than both The 40 Izvora Dam Lake ecosystem and the semi-intensive earth pond system Tri Voditsi /10 experimental base ($P < 0.05$). There were no significant differences with respect to this trace element for the other production systems ($P > 0.05$).

The content of carp meat zinc (Zn) varied from 2.22 mg.kg$^{-1}$ to 8.88 mg.kg$^{-1}$. The zinc concentrations in fish from the net cages were statistically significantly higher vs all other studied groups ($P < 0.01$; $P < 0.001$). A lower level of significance ($P < 0.05$) was established between Tsarimir 1 Dam Lake and Tundzha 73 /5 fish farm. There were no substantial differences with regard to carp meat zinc concentrations among the other production systems ($P > 0.05$).

The analysis of results indicates that the trace element concentrations obtained in this study were comparable to those of Pirestani et al. (2009) for Cu (2.58 mg.kg$^{-1}$), Fe (12.55 mg.kg$^{-1}$) and Zn (7.44 mg.kg$^{-1}$). Regardless of the toxic effects of copper and zinc, they are essential and their presence in food is necessary for human health maintenance. The average copper and zinc values of studied carp meats did not exceed the limits of 10 mg.kg$^{-1}$ for copper and 50 mg.kg$^{-1}$ for zinc specified by Ordinance 31 of the Ministry of Health, 2004. The recommended daily intake of iron is 8–11 mg/day (men) and 8-18 mg/day (women). Comparing the data from the study with recommended amounts for adults, it could be concluded that carp meat from studied groups was rich is iron and one serving (300 g fish) could satisfy the daily needs of adult men and women.

To sum up, the meat of carps reared in production systems with different level of intensity (semi-intensive, intensive and super intensive) and different feeding types (grain feeds, meals, special compound feeds) contains a broad spectrum of macrominerals (phosphorus, magnesium, calcium) and trace elements (iron, copper and zinc) valuable for human health. The meat copper and zinc levels did not exceed the fish quality norms (Ordinance 31 of the Ministry of Health – 2004). The comparison of norms for physiological feeding, the recommended daily intake of the different macro– and trace elements with the results from analysis of meat indicated that one serving of carp meat (300 g) could satisfy entirely the daily needs from phosphorus and iron, up to 1/2–1/4 of the needs from magnesium, potassium and calcium and up to 1/6 – from sodium.

## Conclusions

The content of the primary macrominerals and trace elements in carp meat and its specificity related to the used production system has been established.

It was demonstrated that the prevailing macrominerals were the potassium (2713.86–3552.22 mg.kg$^{-1}$) and the phosphorus (2261.18–2417.86 mg.kg$^{-1}$).

Out of the studied trace elements, carp meat had a higher content of iron (4.43–7.14 mg.kg$^{-1}$) and zinc (2.22–8.88 mg.kg$^{-1}$).

The results from this study could be used as objective information for evaluation of the nutritional value of carp meat with regard to the content of macrominerals and trace elements.

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