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IMPACT OF HABITAT ORIGIN ON THE MICRO AND MACROELEMENT PROFILE OF EUROPEAN CATFISH (*Silurus glanis*)

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Abstract

This study examines how habitat origin influences the macro- and microelement composition of wild and farmed catfish, with emphasis on the distribution of toxic metals across tissues. Mineral levels in liver, bones, head, skin, muscle, and fins were quantified by AAS and ICP-MS. Ca was the dominant microelement, with concentrations up to 4.5% higher in aquaculture fish, followed by potassium (7200 ppm), Na (6066.5 ppm), and Mg (4108 ppm). Fe was the predominant microelement, reaching 363.05 ppm in the liver of wild catfish compared with 342.55 ppm in farmed specimens. Zn and Cu showed the largest habitat-related differences, with levels approximately 19.8% and 16.3% higher, respectively, in aquaculture fish, while manganese remained similar across samples. Microelements accumulated mainly in the liver, followed by skin and fins, and were lowest in muscle and head. Hg occurred only in the head and skin, with levels 2.3 times higher in skin and 2.1 times higher in the head of wild fish. Habitat origin was associated with differences in shaped elemental profiles, underscoring the importance of selecting raw material for safe catfish products.

Key words*: aquaculture catfish, habitat, heavy metal, mineral profile, wild catfish.*

INTRODUCTION

Silurus glanis, known as the European catfish (wels, sheatfish), is one of the largest freshwater fish species in the world, reaching lengths of up to 5 m and body masses exceeding 300 kg (Copp et al., 2009). *Silurus glanis* L., is the principal European representative of the order Siluriformes, noted for its ecological and economic relevance (Saez-Gomez, 2022). They exhibit strong environmental adaptability and occur predominantly in the freshwater systems, although they are occasionally recorded in the salty waters of the Black Sea and Baltic Sea (Severov, 2020; Bergström et al., 2022). The species is native to Eastern Europe and Western Asia, being abundant in the Danube and Volga river basins, but it has been widely introduced into numerous European aquatic systems due to its commercial value and popularity in recreational fishing (Britton, 2007; Carol et al., 2007, 2009). European catfish farming has expanded steadily in recent years, driven by three main factors such as: i) the species have highly palatable flesh, which is particularly valued by consumers in Eastern Europe and Asia (Panicz, 2017; Lyach, 2021; Bergström et al., 2022); ii) its suitability for polyculture systems, where it contributes to maintaining a healthy biocenosis (Vejrik et al., 2019; Linhart et al., 2020); iii) its strong appeal in recreational fisheries in countries such as Spain, the Netherlands, France, and Italy (Rees et al., 2017; Lyach & Remr, 2019; Říha et al., 2022), owing to its impressive size and the notable challenge it presents during capture. From an economic

perspective, *S. glanis* is a species of major importance for both commercial fisheries and aquaculture (Copp et al., 2009). In recent years, the intake of catfish has grown rapidly, driven by its accessibility, reliable quality, and nutritional advantages (Hoke et al., 2000). In general, fish is a nutrient-dense dietary resource, supplying essential vitamins and minerals and offering proteins with a complete and well-balanced profile of indispensable amino acids and catfish also belongs to this category (FAO, 2001). Fish represent an excellent dietary source of macro minerals such as calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), and phosphorus (P) as well as microminerals including iron (Fe), zinc (Zn), copper (Cu), selenium (Se), iodine (I), and manganese (Mn) (Porto et al., 2016). Fish acquire minerals both through dietary intake and directly from the surrounding water, with absorption processes largely influenced by environmental factors, particularly mineral concentrations (Terech-Majewska et al., 2016). Depending on the harvesting environment or the composition of aquaculture feed, fish may also expose consumers to toxic trace elements (Türkmen et al., 2009). In this context, fish are also commonly used as bio-indicators of aquatic ecosystem quality because they are abundant and can readily accumulate heavy metals (Luczynska et al., 2022, Şirin et al., 2024). The distribution of minerals within fish tissues is strongly influenced by habitat and feeding regime. In aquatic environments, both essential and toxic trace elements originate from natural and anthropogenic sources, and the extent of their accumulation in fish tissues varies with pollutant type, species, sampling location, trophic level, and feeding behaviour (Allinson et al., 2009). On the other hand, trace element pollution in aquatic environments is a major concern because it can cause long-lasting damage to ecosystems and endanger human health when these substances enter the food chain (Ali et al., 2016; Chowdhury et al., 2016). Rising levels of trace elements can have toxic effects on invertebrates, fish, and humans due to bioaccumulation and biomagnification. Some of the most harmful trace elements for aquatic ecosystem health and stability include Ni, Zn, Pb, Cr, Cu, Hg, As, and Cd (Martín et al., 2015; Sharma et al., 2023). Impact of 70 years urban growth associated with heavy metal pollution. Environmental pollution, 196, 156-163. The present study aims to highlight the differences in the micro and macroelement composition of farmed and wild catfish harvested in Romania, emphasizing the influence of habitat and feed on the mineral profile of this species.

MATERIALS AND METHODS

Biological material

This study focused on European catfish (*Silurus glanis*) reared/originating from two different environments: 1) an indoor recirculating aquaculture system (RAS), and 2) the wild, natural environment. In the first experimental group, tissue samples were collected in September from 5 European catfish specimens, aged 2 years and 3 months, which had been reared exclusively indoors in a recirculating aquaculture system (RAS). Throughout their entire life cycle, the fish were maintained under indoor farm conditions at the Pădurea Verde Fish Farm, belonging to the University of Life Sciences "King Mihai I" from Timișoara. The fish were fed exclusively with pelleted compound feeds and, during the last year of life, received a Supreme 10 diet with a pellet size of 6 mm (Alltech Coppens, Germany). The body weight of the fish used in the study was 2.362 ± 0.109 kg, and their total length was 68.4 ± 2.074 cm. In the second experimental group, tissue samples were collected from 5 European catfish specimens originating from the Danube River in the Orșova area of Mehedinți County (44°43′31″ N, 22°23′46″ E). These fish were caught in September, at the same time as the farmed fish were sampled. The size of the fish caught and retained for the study was similar to that of the fish from the first experimental group. Thus, their mean body weight was 2.237 ± 0.0912 kg, and their total length was 65.2 ± 2.031 cm. The fish were purchased fresh, cut into anatomical sections, and the following tissues were collected: liver, muscle, skin, bone, fins, and head. All samples were analyzed for moisture and ash content (the results are expressed as wet-weight basis), as well as for the concentrations of microelements (Cu, Zn, Fe, Mn), macroelements (K, Ca, Mg, Na), and trace toxic elements (Hg).

Moisture and ash contents

The moisture and ash content of catfish samples were determined according to ISO standards: moisture was measured following SR 91/2007, section 10, while ash content was assessed using the SR ISO method (SR 91/2007 pct.10 humidity; SR ISO 2171/2010, ash).

Determination of mineral content

Macro and microelement concentrations were determined after sample calcination at 650°C in a muffle furnace (Nabertherm GmbH, Lilienthal/Bremen, Germany) until a constant white ash was obtained. Subsequently, extraction was performed using 20% hydrochloric acid (HCl) (Sigma-Aldrich Chemie GmbH, Munich, Germany). The elemental concentrations: cooper (Cu), zinc (Zn), iron (Fe), manganese (Mn), potassium (K), calcium (Ca), magnesium (Mg), sodium (Na) were quantified by atomic absorption spectrometry (AAS) using a Varian Spectra 240 FS (USA) spectrophotometer. The experimental parameters are detailed in Table 1.

Table 1. The experimental parameters for Varian Spectra 240 FS spectrophotometer

Metal	λ (nm)	Lamp current (mA)	Slit width (mm)	Quantification (LOQ) limit
Cu	324.8	4	0.5	0.0012µg/L
Zn	213	5	1	0.008µg/L
Fe	248.3	5	0.2	0.06mg/L
Mn	279.5	5	0.2	0.025mg/L
Ca	422.7	10	0.5	0.10mg/mL
Mg	282.5	4	0,5	0.011mg/mL
K	414	4	0.5	0.252mg/mL
Na	589	8	0.5	0.028mg/L

Hg was quantified by Inductively Coupled Plasma Mass Spectrometry (ICP-MS) using a PlasmaQuant Elite instrument equipped with an AIM3300 autosampler (Analytik Jena, Germany) according to Djedjibegovic et al., (2012). All analyses were performed in triplicate, and results were expressed in ppb (µg/kg) (González et al., 2025).

RESULTS AND DISCUSSIONS

Tables 2 and 3 present the moisture and ash content of fish tissues originating from wild and aquaculture catfish samples. A substantial variation was also observed in ash content, with the highest value recorded in the bones (56.989%), followed by the head and fins, while the lowest value was found in the muscle (1.279%). The ash content of the skin and liver showed closely similar values.

Table 2. Moisture and ash content of fish tissues harvested from aquaculture catfish samples

Fish tissue	Moisture (% wwb)	Ash (%wwb)
Fins	56.25±1.420	14.096±0.420
Bones	26.989±0.563	56.989±0.563
Skin	54.266±1.770	5.121±0.024
Muscle	78.731±2.435	1.279±0.075
Liver	77.178±2.731	3.038±0.333
Head	61.213±1.699	20.411±0.692

Consistent with the aquaculture specimens, the muscle exhibited the highest moisture level (77.060%), whereas the bones contained the highest proportion of ash (56.091%). Conversely, the bones showed the lowest moisture content (27.019%), while the muscle presented the lowest ash concentration (1.385%).

Table 3. Moisture and ash content of fish tissues harvested from wild catfish samples

Fish tissue	Moisture (%wwb)	Ash (%wwb)
Fins	52.252±1.029	17.2496±0.512
Bones	27.019±0.563	56.091±0.502
Skin	51.343±1.963	5.612±0.030
Muscle	77.060±2.317	1.385±0.086
Liver	71.451±1.922	3.798±0.513
Head	64.385±1.699	18.852±0.486

A comparative assessment of the values determined for tissues belonging to wild and farmed catfishes shows that moisture levels of the bones and head in wild-caught catfish was lower than of the farmed ones, whereas all other analyzed tissues parts showed a slightly higher water content in those belonging to the farmed fish. The ash content of the analyzed catfish samples shows an inverse relationship with their moisture levels, such that tissues with lower moisture exhibited higher ash concentrations (bones and head), whereas tissues with higher moisture displayed correspondingly lower ash levels (all the other analyzed tissues).

The obtained results for the moisture and ash content of the muscle are consistent with those

reported by Mecatti et al. (2017), Pyz-Łukasik & Paszkiewicz (2018), and Barbacariu et al. (2023). No published data were found regarding the moisture content of catfish bones as an individual anatomical tissue.

Mineral content of wild and aquaculture catfish

Figure 1 presents the distribution of macroelements in wild and aquaculture catfish and shows the difference between the values determined for Ca, K, Mg, and Na in the catfish samples originating from the two habitats.

Calcium (Ca) was the most abundant macroelement identified in all samples, occurring predominantly in the bones of catfish from both habitats. The highest Ca concentration was observed in the bones of aquaculture-raised catfish, where levels were approximately 4.5% higher than those measured in wild individuals. Elevated Ca levels were also detected in the skin, followed by the fins and head. Potassium (K) was the next most abundant macroelement, with a mean concentration of 7200 ppm across all tissues in aquaculture catfish and 7091 ppm in wild specimens, showing the highest accumulation in the liver and muscle and the lowest in the skin. Sodium (Na) followed, with average concentrations of 6066.5 ppm in farmed catfish and 5869 ppm in wild catfish, with the greatest levels recorded in the bones, skin, and head. Magnesium (Mg) exhibited the lowest concentrations among the macroelements analyzed, averaging 4108 ppm across all tissues in aquaculture catfish and 3869 ppm in wild catfish, with the highest values found in the bones and skin and the lowest in the head and muscle.

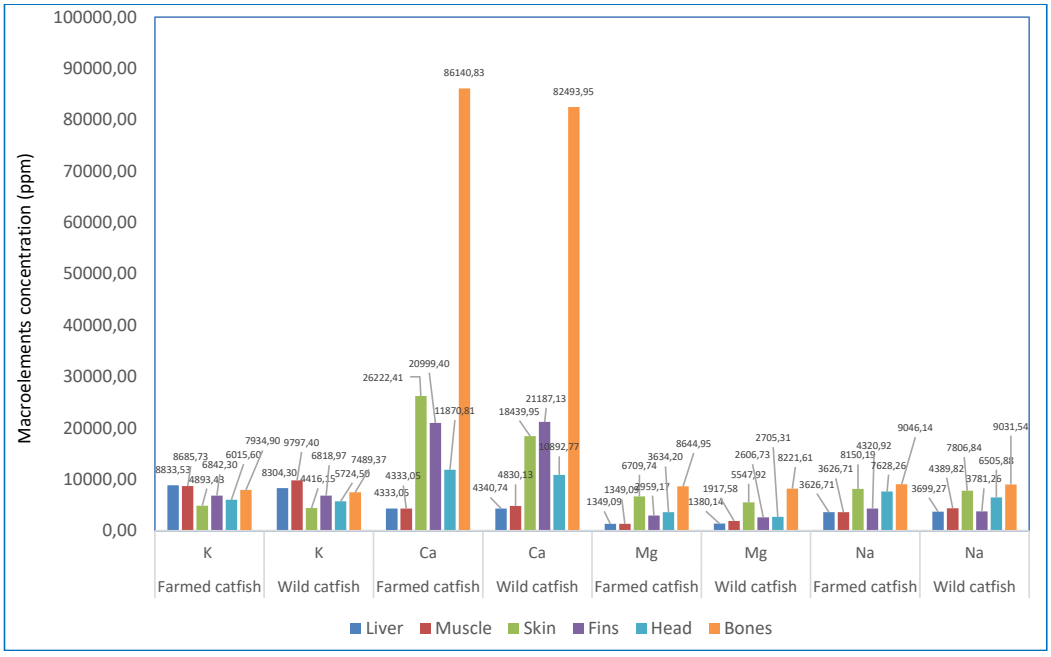


Figure 1 Distribution of macroelements in wild and aquaculture catfish

The obtained results indicate that the concentrations of the analyzed macroelements were higher in all tissues of aquaculture catfish, with an average increases of approximately 10% for Mg, 4.5% for Ca, 3% for Na, and 2% for K. Values reported in other studies reach up to 304.82 mg/kg for Ca, 142.42 mg/kg for Na, and 112.8 mg/kg for Mg in catfish muscle, expressed on a dry-weight basis (Pyz-Lukasik & Chalabis-Mazurek, 2019; Abdel-Mobdy et al., 2021). Furthermore, Matloob (2023) reported concentrations in catfish muscle ranging from 9014 to 10,879 mg/kg for K, 999 to 2039 mg/kg for Na, 797 to 3081 mg/kg for Ca, and 1206 to 1819 mg/kg for Mg, values that are more closely aligned with those obtained in the present study.

The reviewed literature does not report macro-element concentrations in the same tissues that we examined. Figure 2 presents the distribution of microelements in wild and aquaculture catfish, which shows the difference between the values determined for Zn, Fe, Cu and Mn in the catfish samples originating from the two habitats.

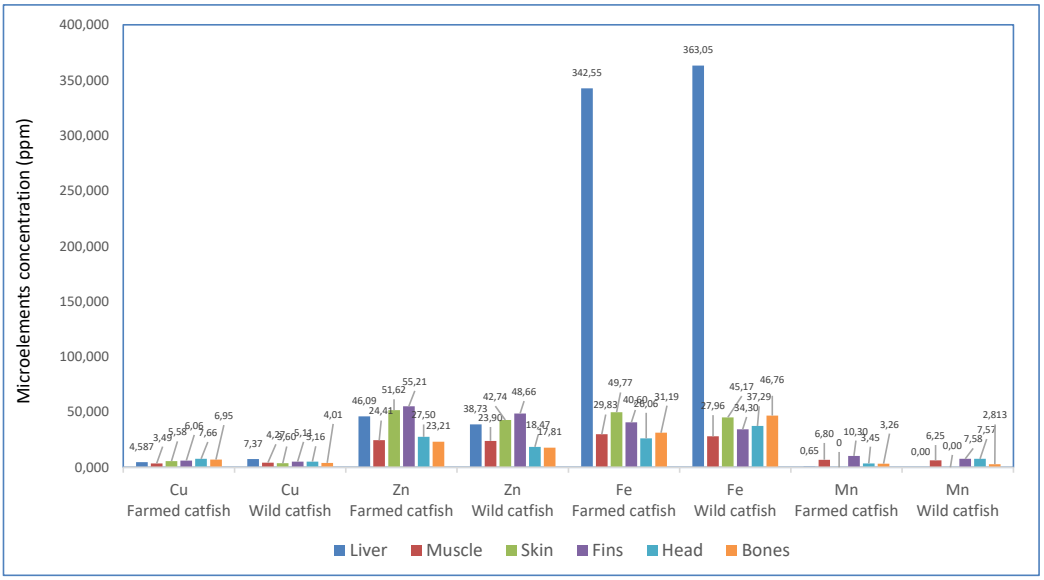


Figure 2. Distribution of microelements in wild and aquaculture catfish

Iron (Fe) was identified as the predominant microelement, with the highest concentration detected in the liver of wild catfish (363.05 ppm), approximately 6% higher than in farmed catfish (342.55 ppm). The lowest Fe concentration was detected in the head of farmed specimens (26.06 ppm). Fe was followed by Zn, with the highest concentrations recorded in fins, skin, and liver. The accumulation pattern was generally similar in the two catfish groups, although most microelements were slightly higher in farmed specimens, except for Fe, which was higher in wild specimens. The greatest habitat-related differences were observed for Zn and Cu, whereas Mn showed only minor variation between groups. Analysis of microelement distribution in catfish tissues showed that the highest concentrations accumulated in the liver, followed by skin and fins, while the lowest concentrations were found in muscle and head.

The values reported in previous studies ranged from 6.73-11.99 mg/kg Fe, 7.09-9.132 mg/kg Zn, 1.15-1.657 mg/kg Cu and 0.34-0.418 mg/kg Mn (Pyz-Lukasik & Chalabis-Mazurek, 2019; Abdel-Mobdy et al., 2021). Jovičić et al. (2015) reported comparable values determined by ICP-MS, namely 19.46 µg/g Fe, 0.670 µg/g Mn, 0.950 µg/g Cu, and 19.62 µg/g Zn in muscle, and 745.7 µg/g Fe, 4.570 µg/g Mn, 5.095 µg/g Cu, and 93.14 µg/g Zn in liver. In another study, Subotić et al. (2013) found (using ICP-MS method) 396.16 µg/g Fe, 1.65 µg/g Mn, 8.37 µg/g Cu and 41.52 µg/g Zn in liver, respectively 27.06 µg/g Fe, 0.44 µg/g Mn, 1.42 µg/g Cu and 20.81 µg/g Zn in muscle. No reported values were found for some of the other catfish tissues examined in the present study.

Hg content of wild and farmed catfish tissues is presented in Table 4.

The low concentrations of mercury detected in the analyzed catfish tissues suggest a low toxicological concern for consumers, particularly given that measurable levels were limited to the head and skin and these tissues are generally less commonly consumed than muscle tissue. In all other tissues Hg was undetectable.

Table 4. Hg in fish tissues collected from aquaculture and wild catfish samples

Fish tissue	Aquaculture catfish (ppb)	Wild catfish (ppb)
Fins	nd	nd
Bones	nd	nd
Skin	0.1±0.026	0.23±0.062
Muscle	nd	nd
Liver	nd	nd
Head	0.557±0.111	1.183±0.047

nd= undetectable

The consulted literature reported Hg concentration of 0.34 mg/kg in muscle and 0.25 mg/kg in liver determined by Direct Mercury Analyser (Squadrone et al., 2013). Also, Alomar et al (2016), detected 0.84 mg/kg (by AAS) in catfish liver, and Subotić et al (2013) reported 1.90 μg/g Hg in liver, respectively 1.63 μg/g Hg in muscle (by ICP-MS).

CONCLUSIONS

This study reveals clear habitat-related differences in the distribution of macro and microelements in wild and aquaculture catfish. Calcium was the dominant macroelement, especially in bones, while iron was the predominant microelement, with the highest levels found in the liver of wild individuals. Microelements generally accumulated in the liver, followed by the skin and fins, and were least abundant in the muscle and head, reflecting consistent tissue-specific patterns.

Habitat influenced several elemental concentrations, with notable differences observed for Fe, Zn, and Cu, whereas Mn remained relatively stable across samples. Mercury was detected only in the head and skin of both catfish groups, and exclusively at low levels that remained well below European and international regulatory limits (FAO, 2017). Hg was undetectable in all other tissues, indicating minimal risk for consumers, particularly since the tissues containing measurable Hg are not typically consumed.

Collectively, these findings provide new insights into mineral distribution in catfish tissues and underscore the role of habitat conditions in shaping elemental profiles, while also confirming the overall safety of the analyzed specimens with respect to mercury contamination.

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