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Investigation of Nutrient and Heavy Metal Content in Carp (*Cyprinus carpio*) in Alleben Pond (Gaziantep)

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ABSTRACT

The biochemical composition and the levels of heavy metal elements of different fish species have grown recently due to concern about its safety and nutritional value. In the current study, the proximate analyses and heavy metal contents of carp (*Cyprinus carpio* L., 1758) obtained from Gaziantep Alleben Pond an artificial pond, were investigated. The results showed that the proximate composition of *Cyprinus carpio* were found as protein (16.33%), lipid (2.17%), moisture (78.44%) and ash (1.31%). The results of heavy metal analyses exhibited that the aluminum (*Al*), iron (Fe), calcium (*Ca*), copper (*Cu*) and zinc (*Zn*) contents in the muscle tissue of *Cyprinus carpio* were found as 20.95 mg/kg, 22.06 mg/kg, 557.62 mg/kg, 1.44 mg/kg and 36.96 mg/kg, respectively. This research has shown that the nutritional value of carp fish is high and that their heavy metal content does not exceed acceptable limits and does not pose any risk to the health of their consumers.

Keywords: *Cyprinus carpio*, Alleben Pond, proximate analyses, heavy metal contents

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Alleben Göletindeki Sazan (*Cyprinus carpio*) larda Besin Madde ve Ağır Metal İçeriğinin Araştırılması

Öz: Farklı balık türlerinin biyokimyasal bileşimi ve ağır metal element seviyeleri, güvenlik ve besin değeri konusundaki endişeler nedeniyle son zamanlarda artmıştır. Bu çalışmada Gaziantep Alleben Göleti'nden elde edilen sazan balıklarının (*Cyprinus carpio* L., 1758) besin kompozisyon analizleri ve ağır metal içerikleri araştırılmıştır. *Cyprinus carpio*'nun besin madde içeriği protein (%16,33), lipid (%2,17), nem (%78,44) ve kül (%1,31) olarak tespit edilmiştir. Ağır metal analizlerinin sonuçları, *Cyprinus carpio*'nun kas dokusundaki alüminyum (*Al*), demir (*Fe*), kalsiyum (*Ca*), bakır (*Cu*) ve çinko (*Zn*) içeriklerinin sırasıyla 20,95 mg/kg, 22,06 mg/kg, 557,62 mg/kg, 1,44 mg/kg ve 36,96 mg/kg olduğunu göstermiştir. Bu araştırma, sazan balığının besin değerinin yüksek olduğu ve ağır metal içeriklerinin kabuledilebilir sınırlarını aşmadığı ve tüketicilerinin sağlığı için herhangi bir risk teşkil etmediğini göstermiştir.

Anahtar kelimeler: *Cyprinus carpio*, Alleben Göleti, besin madde içeriği, ağır metal içeriği

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Introduction

Environmental pollution has reached frightening levels all over the world, threatening the lives of both humans and other living things (Rathod et al. 2025). In particular, the increasing pollution and depletion of aquatic habitats is causing serious economic, ecological and sociological problems. In general, these problems include a decrease in nutrient production, disruption of the ecological balance in aquatic ecosystems, social and political stability problem and an increase in diseases.

One of the biggest causes of environmental pollution is industrialization. Since the second half of the 19th century, the phenomenon of industrialization, which has developed together with urbanization since the Industrial Revolution, has caused significant changes in the economic, social and cultural spheres of the society in which it has occurred. However, the effects of industrialization, which develops along with urbanization, have the greatest impact on the environment. Today, with the impact of industrialization, environmental problems have started to reach dangerous dimensions, especially for industrialized and industrializing cities (Demirarslan and Demirarslan 2018). Increasing industrialization and human activities intensify the release of various pollutants into the environment (Saxena et al. 2025).

Although the aquatic ecosystem is one of the most important ecosystems on Earth, it is seen as both a convenient disposal site and a simple and inexpensive option for many wastes. Discharges such as organic substances, metals, petroleum derivatives, artificial agricultural fertilizers, detergents, radioactivity, pesticides, inorganic salts, artificial organic chemicals and waste heat adversely affect the quality of aquatic environments (Edo et al. 2024; Barik et al. 2025). Due to these threats in the aquatic environment, interest in the determination of heavy metal concentrations has increased and care was taken to measure the levels of contamination in fish. In aquatic ecosystems, various toxic elements such as heavy metals can accumulate via the food chain and create a health hazard (Ray and Vashishth 2024). A variety of foods, including fish, vegetables and cereals, expose people to harmful heavy metals. As a result, heavy metal contamination found in water or plants can biomagnify, remain in the food chain and eventually reach the human body. Heavy metal poisoning has become a serious concern for fish consumers worldwide. Many researchers have determined the levels of heavy metals and minerals in muscle tissue of fish species (Parang and Esmaeilbeigi 2022; Parui et al. 2024; Ali et al. 2024; Ustaoğlu and Yüksel 2024).

Fish has a high nutritional content and is a rich source of lipids, proteins, and other micronutrients that are necessary for maintaining good health (Prakash et al. 2021; Islam et al. 2024). Carp (*Cyprinus carpio*) is a freshwater fish and found in all regions of Turkey; especially in the pools, ponds, lakes and rivers in the Aegean, Central Anatolia and Southern Anatolia regions. In this content, the proximate and heavy metal levels of carp (*C. carpio*) in Alleben Pond in Gaziantep were investigated for nutrient components and heavy metal levels.

Materials and Methods

Materials

The fish used in the study were carp (*Cyprinus carpio* L., 1758) caught in Alleben Pond (Figure 1) in November 2024, brought to the laboratory with cold chain, and stored at −20 ºC until the time of analysis. A total of 10 individual fish were used for the metal concentration analyses in muscle tissue. The specimens had an average total length of 25.0 ± 2.1 cm and a mean weight of 350.0 ± 5.7 g.

Figure 1: *Cyprinus carpio* image

Alleben Pond (Figure 2) is 939 meters above sea level and about 4 kilometers southwest of Gaziantep (37° 04′ 29″ North and 37° 16′ 20″ East). With a capacity of 2.54 hm^3, it is located between 37° 04′ 29″ North and 37° 16′ 20″ East and covers around 149 hectares of agricultural land. Water from spring, rain, and snow feeds this pond, which stretches from Southeast Taurus to the Sof Mountains. In addition to being used for manmade uses and agricultural irrigation, it was constructed to avoid floods. The Alleben stream flows through the heart of Gaziantep and pours into the Kayacık Dam at Oğuzeli from its falls.

Figure 2: Bird's Eye and Ground-Level Views of Alleben Pond
A combined illustration showing Alleben Pond from two perspectives: a bird's eye view (left) and a ground-level image (right), highlighting the spatial layout and visual features of the study area.

Proximate Analyses

Total crude protein ratio analysis was performed according to the Kjeldahl method, in accordance with AOAC Official Method 955.04. (1998), using a nitrogen conversion factor of 6.25. Lipid was measured using Bligh and Dyer (1959) method. For the ash and moisture contents, the AOAC Methods 920.153 (2002) and 950.46 (2002) were used, respectively.

Metal Levels Analysis

The metal contents in the fish samples were ascertained using a modified method of the Canli and Atli (2003). About 0.5 g of wet fish muscle was digested using a solution of 2 mL perchloric acid and 4 mL concentrated nitric acid (Darmstadt, Germany). Only the muscle tissue of the fish was dissected and used for all analyses, as it is the most commonly consumed part. The samples were then heated on a Velp-Scientifica hotplate (Usmate Velate, Italy) to 150 °C until the meat was totally disintegrated. The levels of major toxic metals aluminum (*Al*), iron (*Fe*), calcium (*Ca*), copper (*Cu*), and zinc (*Zn*) were measured in milligrams per kilogram (mg/kg).

The elemental analysis was carried out using an Agilent 7500ce type ICP-MS (Agilent, Tokyo, Japan). The analysis was conducted at CUMERLAB-Çukurova University Central Research Laboratory. Each sample was inspected three times to obtain correctness. Operating indexes for ICP-MS comprised a 1500 W radio frequency, a sample depth (8.6 mm), a sample rate of 1 mL/min, a nebulizer pump speed of 0.1 rps, a 15 L/min plasma gas flow rate, a 1 L/min auxiliary gas flow rate, and a 1.1 L/min carrier gas rate. For calibration, a High-Purity Multi-Standard solution (HPS, Charleston, SC, USA) was applied.

All analytical results are presented as mean ± standard deviation (SD). Each measurement was performed in triplicate to ensure accuracy and reproducibility.

Results

Proximate Analyses

The nutrient constitutes values of carp (*C. carpio* L.,1758) are given in Table 1.

Table 1. Proximate composition of *Cyprinus carpio* (%)

	Protein	Lipid	Moisture	Ash
Carp (*C. carpio* L.,1758)	16.33±0.26	2.17±0.10	78.44±4.17	1.31±0.50

In the current study, the protein, lipid, moisture and ash contents of carp were found as 16.33%, 2.17%, 78.44% and 1.31% respectively.

Metal Levels Analysis

In this study, the concentrations of *Al*, *Fe, Ca*, *Cu*, *Zn* in muscle of *C. carpio* were determined. The samples were obtained from Alleben Pond in November 2024, representing the autumn season, when environmental conditions such as water temperature and feeding activity may influence elemental uptake in fish. The metal levels found in *C. carpio* are given in Table 2.

Table 2. Metal Levels of *Cyprinus carpio* (mg/kg)

	Al	Fe	Ca	Cu	Zn
Carp (*C. carpio* L.,1758)	20.95±3.84	22.06±0.93	557.62±309.63	1.44±0.96	36.96±8.10

Aluminum, *Fe*, *Ca*, *Cu* and *Zn* levels in the muscle tissue of *C. carpio* were found as 20.95, 22.06, 557.62, 1.44 and 36.96 mg/kg respectively. The relatively high standard deviation observed for calcium (557.62 ± 309.63 mg/kg) indicates substantial variation among individual fish. This variability may be attributed to biological factors such as size, age, diet, and physiological condition. It should also be noted that this value is based on measurements from 10 individual fish and is reported as mean ± standard deviation (SD).

Discussion

The proximate composition of carp (*C. carpio* L., 1758) in Seyhan Dam Lake were investigated by Ayas et al. (2005). The crude protein of carp was determined as 17.20% and crude fat content of carp was 5.96%. The moisture content of carp was 75.34% whereas the crude ash level was 1.16%. Mahboob et al. (2018) were determined that protein, lipid, moisture and ash values of fresh carp (*C. carpio)* were 15.86 %, 5.08%, 71.30% and 4.18%, respectively. Prakash et al. (2021) studied the proximate composition of Indian major carp (*Catla catla*) in the district of Sant Kabir Nagar, Uttar Pradesh, India. They reported that the protein content ranged from 16.57 to 17.66 % whereas lipid level was in the range of 2.86-3.43%. The range of ash content of carp was 2.45-3.19% while the range of moisture level was between 74.37-77.03 %. The chemical composition of carp meat was studied by Makarova et al. (2019) and they reported moisture 80.23%, crude protein 16.55%, fat 1.92% and ash 1.30 %. Kaliniak-Dziura et al. (2024) studied the proximate composition of fillet of *C. carpio.* It was reported that the protein and lipid contents of carp were found as 17.0% and 5.1% while the moisture and ash levels were 77.8% and 1.2%, respectively. These changes in the proximate composition of fish are attributed to a variety of factors such as diet, fish age, sex, species, seasonal fluctuations, and environmental conditions (Rasul et al. 2021; Jan et al. 2025). The results of this study (Table 1) are consistent with the previous studies.

The heavy metal of carp (*C. carpio* L., 1758) samples caught from different regions of Karacaören (Isparta-Burdur) Dam Lake between 2011-2012 in four seasons were analyzed for some heavy metal accumulation through muscle tissue (Erdoğan 2014). Aluminum and *Cr* were below <0.01 mg/g in winter and autumn months, and based on the results in spring and summer months, the average value of *Al* was 6.49 and *Cr* was 0.64 mg/g. The *Fe*, *Mn*, *Cd* values were 17.42, 0.17 and 0.05 mg/g in the summer, respectively. Since *Zn* and *Pb*, were found in all seasons, the average was found to be 14.56 for zinc and 29.59 mg/g for lead.

In an another study by Zafarzadeh et al. (2018), the concentrations of *Pb*, *Cu*, *Zn* and *Cd* in water and muscle of *C. carpio* fish were determined. The mean concentrations of *Cu*, *Zn*, *Pb* and *Cd* were reported as 7.92 mg/kg, 120.90 mg/kg, 5.84 mg/kg, and 0.02 mg/kg. With the exception of *Cd*, *Cu*, *Zn* and *Pb* concentrations were higher than the Food and Agriculture Organization of the United Nations (FAOUN 2016) maximum guidelines.

Heavy metal accumulations of lithium, beryllium, boron, chromium, manganese, cobalt, nickel, copper, zinc, rubidium, lead, strontium, cadmium, arsenic, vanadium and uranium in the muscle and liver tissues of *C. carpio* caught from three different locations of Büyük Menderes River were evaluated (Emek 2019). The average heavy metal levels in fish from three different regions analyzed were in muscle tissue *Cr*: 1.33, *Mn*: 0.32, *Fe*: 23.42, *Ni*: 0.67, *Cu*: 1.43, *Zn*: 12.51, *Pb*: 0.45, *Cd*: 0.094 mg/l and *Cr* and *Cd* levels were found to be above the limit values. *Cr, Mn, Fe, Ni, Ni, Zn, Pb and Cd* heavy metals were observed at higher levels in the liver, while Be, B, Co, Rb, Sr and As heavy metals were found at higher levels in the muscle tissue. They concluded that the consumption of fish obtained from all three regions by humans may be risky in terms of health.

Tkachenko et al. (2021) determined the contents of minerals (manganese, iron, copper, zinc, magnesium, calcium, cobalt, sodium, selenium, phosphorus, potassium, aluminum, chromium) in the muscle tissue of carp. The chemical analyses indicated that the muscle tissue of the common carp was rich in calcium (78.40 $mg{\cdot}kg^{-1}$). Aluminum, *Fe*, *Cu* and *Zn* values in carp muscle tissue are 0.94, 0.37, 0.035, 0.73 mg·kg⁻1, respectively. In addition, Kareem et al. (2022) investigated heavy metal concentrations (mg/kg) in the dorsal muscle of common carp (*C. carpio*) from the Dukan lake, Suleimani, Iraq. They found *Fe, Cu*, and *Zn* levels as 74.31, 6.22, 56.23 mg/kg, respectively. Table 3 shows the most common permissible limits of heavy metals in aquatic environments for fish.

Table 3. The common permissible levels of heavy metals in fish (Kareem et al. 2022)

Heavy Metals	Freshwater (mg/L)	Seawater (mg/L)	References
Fe	434.78	531	FAO (1983)
Cd	0.05	1.0	WHO (1991)
Cr	5	5	FAO (2018)
Cu	0.1	2	Balasim et al. (2013)

Based on their impact on biological systems, metals can be classified as essential or non-essential. Essential components are either a component of organic structures with crucial functions in humans or are required to maintain physiologically significant processes (Ngu et al. 2022). They become hazardous, especially at higher concentrations. Co, *Cu, Cr, Mn, Fe, Mo, Zn* and *Se*, are among the elements that are considered essential whereas non-essential trace elements include, *As, Al, Cr, Cd, Ni, Hg, Pb, Sn, U* and *Sb* (Nunzio et al. 2022).

Iron is one of the essential element, whose Latin name is ferrum, has an atomic number of 26 and is widespread in the earth's crust. Its atomic weight is 55.85 g/mol and its density is 7.874 g/cm3. Iron melts at 1535 ºC and its boiling point is 2750 ºC (MTA 2017). Iron -the most abundant transition element- and its high oxidation state chemistry are of fundamental importance in various (bio)catalysts (Keilwerth et al. 2024).

WHO (1989) reported the upper permissible limit for Fe in seafood as 100 ppm (mg/kg). In our study, it was determined that *Fe* level was found (22.06 mg/kg) below the permissible limit value determined by WHO. The UK Ministry of Agriculture, Forestry and Fisheries (MAFF) maximum consumable limit is 20 mg/kg wet weight (EC 2006).

Aluminum is among the non-essential trace element. The most prevalent metal in the lithosphere is aluminum, which may be found in hydroxides, oxides, and silicates. Despite being scarce in the water, aluminum is extremely harmful to fish; nevertheless, the degree of toxicity varies according on temperature, pH, and the presence of both organic and inorganic ligands. Aluminum is most hazardous between pH 5.0 and 6.0, and its toxicity increases when water's pH rises because to aluminum polymerization. Because of its buildup on the gill surface during polymerization, aluminum causes hypoxia in fish. Numerous studies have documented aluminum's neurotoxicity and cardiotoxicity to fish. According to the Bureau of Indian Standards, 0.2 mg/mL of aluminum is the maximum amount that can be present in drinking water (Das and Ray 2022). By inhibiting antioxidant enzymes and producing excessive amounts of reactive oxygen species through the fentom reaction, aluminum causes oxidative stress in mammals. Additionally, aluminum damages fish gills, causes respiratory, osmoregulatory, and ionoregulatory problems, and ultimately kills the fish. Aluminum also has a significant impact on fish development, biochemical, hematological, and histopathological characteristics (Ray and Vashishth 2024). In 2011, the Joint FAO/WHO Expert Committee on Food Additives (JECFA) established a Provisional Tolerable Weekly Intake (PTWI) of 2 mg/kg body weight for aluminum through food consumption. Based on this threshold, the aluminum level (20.95 mg/kg) detected in the muscle tissue of *C. carpio* in this study does not pose a potential health risk for consumers.

Calcium is the most abundant element in the body and is a must-have. It also plays a regulatory role in many enzyme systems (Çiftçi et al. 2021). One of the main macroelements in living things is Ca, which is mostly used as structural material. Remarkably, 99 percent of the calcium in the body is kept in the skeletal structure, where it combines with phosphorus to generate calcium phosphate, or hydroxyapatite (Shaker and Deftos 2023). The skeleton shields the body's vulnerable interior organs in addition to supporting it and keeping it in form. Furthermore, movement is made possible and development potential is indicated by the locomotor system, which is made up of the skeleton and associated muscles (Bornstein et al. 2021). A lesser portion of calcium (1%) is located outside the skeletal system and is essential for a number of physiological functions, including as muscle contraction, blood coagulation, biomolecular adhesion, cell division, and nerve signal transmission (Bandzerewicz and Gadomska-Gajadhur 2022). Enzyme activities that hydrolyze proteins, phospholipids, and polysaccharides depend on calcium, which also influences hormone production, cell death, membrane permeability, and cytoplasm viscosity (Matuszewski et al. 2020). Calcium is an essential macronutrient, and international authorities such as FAO/WHO have not established a maximum permissible limit for its concentration in fish muscle. According to FAO/WHO (2002), the recommended daily intake of calcium for adults ranges from 1000 to 1300 mg/day. The level of calcium found in this study (557.62 mg/kg) is within an acceptable range and does not raise any toxicological concern.

Both humans and animals have Cu, a trace metal that is essential. Enzymes that include copper can function as oxygen transporters (hemocyanin) or redox catalysts (cytochrome oxidase, nitrate reductase). A vital compound of skin, hair, bones, and several internal organs, copper is essential for bodily processes (Ahmad 2023; Günal et al. 2024). Under normal conditions, copper is a necessary component of metabolic activities involving vitamins, fatty acids, and amino acids. An adult human's usual daily consumption of copper is in the range of 50 and 120 mg. Copper has several functions as a biocatalyst in human metabolism and is found in the structure of metalloenzymes. Tyrosinase, amine oxidase, ascorbic acid oxidase, urate oxidase, superoxide dismutase, cytochrome oxidase, and dopamine βhydroxylase are some of the most well-known copper metalloenzymes. Additionally, the body needs iron to function correctly. Without copper, iron cannot bind to hemoglobin. Copper is present in every tissue and organ in the human body. Absorption of copper occurs in the small intestine and then copper is distributed throughout the body by loosely attaching to amino acids and serum albumin because it is both required and toxic. Copper that enters the liver as copper-albumin and copper-histidine complexes is used in parenchymal cells to manufacture ceruloplasmin. About 90% of the copper in mammalian plasma is found in ceruloplasmin and copper metalloprotein, according to Rafati Rahimzadeh et al. (2024). It accumulates in marine life with copper shells and algae, where it makes its way up the food chain. This metal may build up in the tissues of animals and can have dangerous effects when the level in the tissues reaches dangerous levels. It has been shown that this metal exposure results in pathological changes in a number of organs, most frequently the liver and kidneys. Copper may damage liver cells, leading to hepatotoxicity, or liver disease. Furthermore, it could cause edema, inflammation, or damage to the liver's tissue (Karageçili and Karadaş 2024). In the current study, Cu level was found 1.44 mg/kg which is lower than limit set by FAO/WHO (2002) 30 mg/kg.

A trace metal found naturally in rocks, soil, and aquatic settings is Zn. However, human activities including fertilizer use, mining, industrial processes, and wastewater discharges can raise the amounts of zinc in aquatic environments. Aquatic species biologically absorb zinc as a result of this increase. Specifically, aquatic organisms including fish, zooplankton, phytoplankton, and crustaceans take zinc in its accessible forms. Through the food chain, Zn is transferred from aquatic species to humans (Sonone et al. 2020). During this process, zinc is absorbed by low trophic level organisms such as zooplankton and phytoplankton. Higher trophic level fish and shellfish build up the zinc burden. Zinc enters the human body through the eating of seafood. Zinc poisoning may result from this mechanism, particularly in regions with high levels of industrial pollution. Zinc is one trace element that the human body needs and is crucial for immune system function, cell division, wound healing, and DNA synthesis. However, it might have harmful consequences if taken in excess. Diarrhea, vomiting, and nausea are possible symptoms (Patil et al. 2023). By preventing the absorption of other trace elements (like copper), too much zinc might impair immunity. Neurotoxic consequences can result from prolonged high zinc exposure. The Zn limit levels reported by FAO (1983) and Turkish Food Codex (2011) are 30 and 50 µg/g respectively. The UK Ministry of Agriculture, Forestry and Fisheries (MAFF) has set a maximum consumable limit of 50 mg/kg wet weight (EC 2006). In this study, it was observed that the Zn content of carp was within the permissible limit values (36.96 mg/kg).In conclusion, the study conducted on *Cyprinus carpio* from Gaziantep Alleben Pond revealed that the species possesses nutritional value, indicating as a good source of nutrients. The metal concentrations, including Fe, Cu, and Zn, were found to be below the permissible limits set by international organizations such as WHO, FAO, and UK MAFF. These findings (Table 2) indicate that the consumption of this freshwater fish does not pose a health risk in terms of heavy metal contamination. However, considering the potential for environmental and industrial pollution to affect aquatic ecosystems over time, it is recommended that metal levels in this species be monitored periodically to ensure consumer safety.

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