# Farmed Turkish salmon: Toxic metals and health threat

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**Abstract:**

*Introduction*. Toxic metals in fish, even at low levels, have negative consequences for human health. Even essential metals pose a health threat if consumed in certain quantities. Mercury, cadmium, and lead are the most frequent metals containing in fish. The research objective was to inspect the quality of aquaculture fish found in most major grocery chains across Turkey.

*Study objects and methods*. The present research featured the quantities of Zn, Fe, Cu, Al, Pb, Hg, and Cd in Turkish salmon. The sampling took place between February and June 2019. The cumulative carcinogenic and non-carcinogenic risk for consumers was evaluated based on trace element levels in a prospective health risk assessment using the U.S. EPA model of lifetime exposure.

*Results and discussion*. Fe proved to be the most abundant element in fish fillets, followed by Zn and Cu. Other elements appeared to be far below the permissible values, namely Al ≤ 0.5, Cd ≤ 0.02, Pb, and Hg ≤ 0.05. All the trace elements detected in Turkish salmon were below the reference dose values. The percent contribution to total risk by Fe, Cu, and Zn were 34.20, 24.80, and 41.01%, respectively. The hazard index was ≤ 1. The contamination of aquaculture fish fillet proved insignificant, and the carcinogenic risk was entirely negligible.

*Conclusion*. The research revealed no hazardous trace elements, and their cumulative effects were not indicated in the hazardous index.

**Keywords:** Salmon, heavy metals, estimated daily intake, hazard index

## INTRODUCTION

Rainbow trout from North America is one of the most profitable members of the family in Turkish freshwater farming. Black Sea trout, also known as Turkish salmon, has now taken its place on the Turkish fish market, following the decision of the General Directorate of Fisheries and Aquaculture of the Ministry of Agriculture and Forestry. Turkish salmon grows in dam lakes until its weight reaches 180–220 g. After that, it is put into farms in the cold-water areas of the Black Sea. It is harvested when it weighs 3–4 kg.

In 2019, fish farms produced 116 053 tons of Turkish Salmon in inland waters and 9692 tons in sea farms [1]. This amount is constantly increasing compared to previous years. Farmed trout from Turkey's southern Black Sea littoral proved to be a rich nutritional source of fatty and amino acids, which normalize atherogenicity and thrombogenicity indices of blood [2].

Trout is mobile and prefers clean and oxygen-rich waters. As a result, even a slight contamination affects this fish, long before the water quality deteriorates. Even at low concentrations, metals in contaminated foods have harmful effects on human health [3]. Metal contamination occurs in nature; nevertheless, human activities, such as mining and heavy industry, have severe consequences for ecosystems and aquatic environment. Despite advancements in sewage effluent technology, sewage discharge remains a major challenge in many developing countries [4].

Metals have a strong impact on marine environment and make their way into human food chains. Such toxicants as Hg, Cd, and Pb are associated with fish consumption. Methyl Hg poisoning induced by prenatal ingestion of contaminated fish causes infant mortality and severe birth defects, such as mental retardation, cerebral palsy, and various neurological disorders [5–7]. When Cd is deposited in the proximal tubular cells of the kidney, it causes renal failure because of the decreasing glomerular filtration rates [8]. Pb poisoning affects renal, hematological, cardiovascular, gastrointestinal, and reproductive systems. Moreover, skeletal abnormalities may occur as a result of renal dysfunction and Pb accumulation in the bones [9–11].

Even though some metals are necessary, when their level in the tissues exceeds a certain threshold, they damage both individual organs and the entire organism.

Fish, as an essential aquatic food in the human food chain, has often been tested for metal contamination [3, 12–14]. Several studies have identified metal residues in various fish species, including trout. Rainbow trout has also been subjected to toxicological studies, which detected accumulation in tissues and liver even at low concentrations of Zn [15].

The current research dealt with both cancer and non-cancer hazards associated with trace elements (Fe, Zn, Cu, Al, Pb, Hg, and Cd) in Turkish salmon. Despite the fact that wellness threat assessment models were predominantly created in Europe and the United States, the European model is still in development, getting ever more complex [16]. The American model, according to Gržetić and Ghariani, is detailed and accurate [16]. It is accessible through the Risk Assessment Information System (RAIS), which is backed up by chemical characteristic established and gathered by the U.S. Environmental Protection Agency (U.S. EPA) Integrated Risk Information System [17]. Following [18–22], this research was based on the American model produced by the U.S. EPA [23, 24].

## SRUDY OBJECTS AND METHODS

**Turkish salmon samples collection.** The object of the study was Turkish salmon collected from the Yakakent farm between February and June 2019 (three individual samples per month). The samples were randomly picked from fish offered for sale (Fig. 1). The samples were washed, stored in iceboxes, and transported to the Hydrobiology Laboratory, the Department of Fisheries, to be tested for Fe, Zn, Cu, Al, Pb, Hg, and Cd. Prior to the analysis, the fish samples were documented for the required biological parameters, e.g. wet body weight and total length. The measurements were based on the European Parliament's Animal Care and Use Directive on the Protection of Animals Used for Scientific Purposes [25]. After that, the samples were filleted (Fig. 2), put into polyethylene bags, and stored at 21°C.

**Analytical procedures.** The trace elements in the Turkish salmon fillets were determined by

inductively coupled plasma mass spectrometry (ICP-MS) after applying the pressure digestion method at an environmental food analysis laboratory accredited in Turkey (TÜRKAK Test TS EN ISO IEC 17025 AB-0364-T). European Standard method EN 15763 was used to determine trace elements using acid, wet digestion, and standard reference material. The outputs were presented as mg/kg wet wt.

**Daily trace elements intake.** Risk evaluations for infants, children, and adults were conducted in order to determine the potential hazards that may arise as a result of consuming heavy metals with Turkish salmon. The risks were defined by calculating the probability of health hazard based on potential exposure. The risk exposure depended on the daily consumption of elements (mg/kg body weight per day). The estimated daily intake (EDI) was calculated using element levels and the amount of the fish consumed. The EDI of trace elements was calculated using the following equation:

$$EDI = \frac{C_{metal}\left(\frac{mg}{kg}\right) \times W_{fish}\left(\frac{kg}{day}\right)}{BW\ (kg)} \quad (1)$$

where $C_{metal}$ is trace elements levels in the fillet; $W_{fish}$ is the daily mean consumption of the fillet, which was reported as 0.041, 0.027, and 0.013 kg/day for adults, children, and infants, respectively [26]; and BW refers to an average adult's body weight of 70 kg, a child's weight of 30 kg, and an infant's weight of 10 kg.

**Carcinogenic and non-carcinogenic risks.** The incremental lifetime cancer risk (ILCR) model was used to predict the likelihood of cancer risks in the fish caused by exposure to carcinogenic trace elements:

$$ILCR = CDI \times SF \quad (2)$$

where CDI stands for chronic daily consumption of a carcinogen in mg/kg of body weight per day, and refers the lifetime mean diurnal dose of exposure to the carcinogen. The cancer risk connected with the exposure



**Figure 1** Turkish salmon



**Figure 2** Fillet of Turkish salmon

to a carcinogenic or potentially carcinogenic material was calculated using slope factors (SF) [17].

If the ILCR was < 10⁻⁶, it was regarded negligible; if it was 10⁻⁶ < ILCR < 10⁻⁴, it was assessed as permissible or tolerated; if the ILCR > 10⁻⁴, it was acknowledged as substantial. The carcinogenic and non-carcinogenic CDI values were obtained using the following formula [17]:

$$CDI_{car.} = \frac{C_{fish}\left(\frac{mg}{kg}\right) x\ EF\left(\frac{350\ days}{year}\right) x\ ED\ (26\ years)\ x\ FIR\left(\frac{41000\ mg}{day}\right) x\ \frac{10^{-6}\ kg}{1\ mg}}{AT\left(\frac{365\ days}{year} x\ LT(70\ years)\right) x\ BW\ (70\ kg)} \quad (3)$$

$$CDI_{non-car.} = \frac{C_{fish}\left(\frac{mg}{kg}\right) x\ EF\left(\frac{350\ days}{year}\right) x\ ED\ (26\ years)\ x\ FIR\left(\frac{41000\ mg}{day}\right) x\ \frac{10^{-6}\ kg}{1\ mg}}{AT_a\left(\frac{365\ days}{year} x\ ED\ (26\ years)\right) x\ BW\ (70\ kg)} \quad (4)$$

where CDI is the chronic daily intake of carcinogen; $C_{fish}$ is the trace element concentrations in the fillet; EF is the exposure frequency; ED is the exposure duration; FIR is the fish ingestion rate for adults; AT is the averaging exposure time for non-carcinogenic effects and 70 years of lifetime (LT) for carcinogenic effect; $AT_a$ is the averaging exposure time for non-carcinogenic effects and 26 years of exposure for carcinogenic effect; BW is the body weight.

Many recent studies used the Target Hazard Quotient (THQ) to peruse the potential non-carcinogenic effect of elements in the edible tissues of fish. In the present study, THQ was computed using the following equation to assess non-carcinogenic risks for trace elements in the fillet for adults [27–33]:

$$THQ = \frac{CDI}{Rf.D.} \quad (5)$$

where Rf.D. is an estimate of daily exposure that is unlikely to have significant adverse effects over the lifetime.

The U.S. EPA oral reference doses for Fe, Zn, Cu, Al, and Cd are 0.7, 0.3, 0.04, 1.00, and 0.001 mg/kg/day, respectively [23, 24]. The Rf.D. value for Hg inorganic salts is 0.0003 in the Risk Assessment Information System (RAIS). However, there is no Rf.D. value for Pb and its compounds [17]. The oral slope factor, on the other hand, is only indicated for Pb and its compounds as 0.0085 mg/kg/day [17]. The Hazard Index (HI) was found by summing up the THQs, as illustrated by the equation below:

HI= THQ (Fe) + THQ (Zn) + THQ (Cu) + THQ (Al) + + THQ (Pb) + THQ (Hg) + THQ (Cd) (6)

In the current study, the term "non-carcinogenic effect" (HI) describes the cumulative non-carcinogenic effect. If HI > 1.0, the CDI of a certain element exceeds Rf.D, which indicates that the element poses a potential risk.

**Statistical analysis.** The statistical analysis was performed using the statistical software SPSS Version 21.0. The one-way analysis of variance (ANOVA) was used to examine the difference in trace element quantities in the fish samples across months, followed by Duncan's post hoc test. The threshold for significance was set at $P < 0.05$.

## RESULTS AND DISCUSSION

Fifteen Turkish salmon were purchased for trace element analysis. The fish had an average length of 51 cm and a weight of 2.90 kg.

**Trace elements in the Turkish salmon.** The concentrations of the trace elements observed in the samples of Turkish salmon were generally low (Table 1). Fe appeared to be the most abundant element, followed by Zn and Cu. As long as they do not exceed certain concentrations, such essential elements as Fe, Zn, and Cu are not harmful to biota, including fish.

No Al, Pb, Hg, and Cd concentrations were determined in the fillet samples. In both the European Union Commission Regulation and Turkish Food Codex, the maximum allowable values of carcinogenic Pb, Hg, and Cd are 0.3, 0.5, and 0.05 mg/kg wet wt., respectively [34, 35]. However, neither the European Union Commission Regulation nor the Turkish Food Codex gives any permissible values for Fe, Zn, Cu, and Al [34, 35]. These elements were far below the

**Table 1** Trace elements content in the fillet of Turkish salmon

| Months | Content, mg/kg wet wt. | | | | | | |
|---|---|---|---|---|---|---|---|
| | Fe | Zn | Cu | Al | Pb | Hg | Cd |
| February | 3.9ᵃ | 2.2ᵃ | 0.13ᵃ | < 0.5ᵃ | < 0.05ᵃ | < 0.05ᵃ | < 0.02ᵃ |
| March | 4.2ᵃ | 2.3ᵃ | 0.11ᵃ | < 0.5ᵃ | < 0.05ᵃ | < 0.05ᵃ | < 0.02ᵃ |
| April | 4.8ᵇ | 2.7ᵇ | 0.23ᵇ | < 0.5ᵃ | < 0.05ᵃ | < 0.05ᵃ | < 0.02ᵃ |
| May | 5.5ᶜ | 2.6ᵇ | 0.24ᵇ | < 0.5ᵃ | < 0.05ᵃ | < 0.05ᵃ | < 0.02ᵃ |
| June | 6.7ᵈ | 3.1ᶜ | 0.33ᶜ | < 0.5ᵃ | < 0.05ᵃ | < 0.05ᵃ | < 0.02ᵃ |
| Mean ± SD | 5.02 ± 1.12 | 2.58 ± 0.35 | 0.21 ± 0.08 | < 0.5 | < 0.05 | < 0.05 | < 0.02 |

Letters a, b, c, and d show statistically significant differences ($P < 0.05$)

**Table 2** Estimated daily intake (EDI) of trace elements in Turkish salmon farmed in Yakakent

| Trace elements | Rf.D. Values | EDI (2019) mg/day/ kg body wt. | | |
|---|---|---|---|---|
| | | Infants | Children | Adults |
| Fe | 0.7 | 0.006526 | 0.004518 | 0.00294029 |
| Zn | 0.3 | 0.003354 | 0.002322 | 0.00151114 |
| Cu | 0.04 | 0.0002704 | 0.000187 | 0.00012183 |
| Al | 1.00 | – | – | – |
| Pb | – | – | – | – |
| Hg | 0.0003 | – | – | – |
| Cd | 0.001 | – | – | – |

permissible values, namely Al ≤ 0.5, Cd ≤ 0.02, and Pb and Hg ≤ 0.05.

The sequence of trace elements according to contamination was Fe > Zn > Cu > Al > Pb = Hg > Cd. The reason for the low amounts of Al, Pb, Hg, and Cd could be that the fish farms are located in areas not contaminated by urban or rural sewage. The toxic quantities of Fe, Zn, Cu, Al, Pb, Hg, and Cd in seafood may have a negative impact on consumers' health. As a result, fish farms in coastal areas may be heavily contaminated with non-carcinogenic and carcinogenic hazardous materials that pose a substantial risk to human health. Thus, trace element levels in fish from this area should be regularly monitored and assessed.

In fact, the toxic elements in fish depend on water, food, and sediment. However, accumulation of these elements in food and water usually depends on other factors, e.g. metabolic rate, physiology, ecology, contamination tendency of food, sediment, and the temperature, salinity, and solubility of water, as well as on the interaction of these parameters.

In this study, food intake and uncontaminated water column had an important effect on the amount of trace elements in Turkish salmon, which resulted in a considerable decrease in the toxic elements in question. As metabolic activity decreases with growth and a proportionally lower food intake, the accumulation of

elements decreases quite naturally. The trace elements in Turkish salmon farmed in Yakakent appeared to be below the permissible thresholds set by international and national organizations, confirming the results obtained by other researchers who studied trace element accumulation in trout [31, 36].

**Estimated daily intake of trace elements.** Table 2 illustrates the EDI values of Turkish salmon farmed in the Black Sea of Yakakent in 2019 for adults, children, and infants.

The toxicity of trace elements in humans is determined by their daily intake. In Turkey, the average fish consumption per adult is still low and remains at 15–20 g/day, compared to the recommended amount of 41 g/day [1, 26]. However, people who live near the coast consume far more fish than those who live in continental Turkey. As a result, the research relied on the data approved by the UN Scientific Committee on the Effects of Atomic Radiation [26]. The consumption of these contaminated fish parts puts the health of the local population at risk.

The EDI calculated for all chemical elements in the fish samples was compared with the toxicologically acceptable level and the oral reference dosage (Rf.D. values). The intake of all the trace elements was below the Rf.D. limits. Thus, the trace elements in Turkish salmon pose no threat for the population of the region.

**Human health risks.** The Risk Assessment Information System classifies Cd, Hg, and Pb as carcinogenic agents [17]. Chronic exposure to even low levels of Cd, Hg, and Pb could lead to a variety of cancers. If it exceeds a certain threshold value, it can have a carcinogenic effect. Table 3 demonstrates a lifetime risk analysis for Turkish salmon consumers.

Percent contribution to total risk by Fe, Cu, and Zn was determined as 34.20, 24.80, and 41.01%, respectively. According to U.S. EPA, at ILCR $10^{-6}$, cancer threat is insignificant, the threshold risk limit of ILCR > $10^{-4}$ requires preventive medical measures, while ILCR > $10^{-3}$ signals that local public health is under threat. In the present study, the samples of Turkish

**Table 3** Chronic Rf. D values, oral slope factor (SP), non-carcinogenic and carcinogenic chronic daily intake (CDI), target hazard quotient (THQ), hazard index (HI), and incremental lifetime cancer risk (ILCR) of trace elements in Turkish salmon in 2019

| Elements | Chronic Rf.D., mg/kg/day | Oral slope factor (SF), mg/kg/day | Noncarcinogenic CDI, mg/kg/day | Carcinogenic CDI, mg/kg/day | THQ | ILCR |
|---|---|---|---|---|---|---|
| Fe | 7.00E-01 | – | 2.82E-03 | 1.05E-03 | 4.03E-03 | |
| Zn | 3.00E-01 | – | 1.45E-03 | 5.38E-04 | 4.83E-03 | |
| Cu | 4.00E-02 | – | 1.17E-04 | 4.34E-05 | 2.92E-03 | |
| Al | 1.00E+00 | – | – | – | – | |
| Pb | – | 8.5E-03 | – | – | – | – |
| Hg | 3.00E-04 | – | – | – | – | |
| Cd | 1.00E-03 | – | – | – | – | |
| HI | | | | | 1.18E-02 | – |

salmon posed no cancer risk. Since none of the cancer-causing trace elements were detected, Turkish salmon consumption can be considered beneficial. However, a regular control the contamination levels of farmed fish is essential.

Chemicals can be either non-carcinogenic or carcinogenic in health risk assessments. Non-carcinogenic trace elements have a threshold limit. Therefore, they are regarded as having no adverse health effects at doses below the threshold level computed using the dose-response assessment method based on the specific reference dose for each element. Carcinogenic substances, on the other hand, are believed to have no effective threshold limits. This assumption implies that even low doses of the chemicals mean a low risk of cancer developing over time. As a result, there is no such thing as a safe level of exposure to carcinogenic substances [21]. In this sense, risk analysis and regular follow-ups are essential for human health.

The research also featured non-cancer risks of the trace elements in Turkish salmon. The risk level of hazard quotients (HQ) for adults was monitored for Fe, Zn, Cu, Al, Pb, Hg, and Cd. It revealed that consuming these trace elements through a fish-based diet posed a significant non-cancer risk. Individual ingestion of these trace elements from Turkish salmon in this region, on the other hand, is safe (HQ < 1) for the local population. Bat *et al.* and Yardim and Bat have obtained similar results [31, 35]. The cumulative HI, which is the sum of individual trace element THQs, was also used to describe the non-cancer hazards posed by Turkish salmon. Since the total of hazard quotients was $\leq 1$, Turkish salmon revealed no potential risk for human health.

## CONCLUSION

The hazard index was < 1, so the concentrations of trace elements (Fe, Zn, Cu, Al, Pb, Hg, and Cd) proved to pose no health threat via consumption. Adults, children, and infants had the same risk ranking, although infants were at a higher risk due to their low body weight. However, since Turkish salmon revealed no carcinogenic trace elements, and the non-carcinogenic trace elements were quite low, no consumer in any group is at risk. Risk within the non-carcinogenic trace elements in Turkish salmon was as follows: Zn (41.01%) > Fe (34.20%) > Cu (24.80%).

Food safety requires an intensive study program and longitudinal studies on the health risk of trace elements in aquaculture products cultivated in Turkey's coastal waters, regardless of how safe the current results are. The practice of health management, according to Bassey *et al.*, begins with routine monitoring by regulatory bodies, toxicologically assessment of wastewater using conventional procedures, and raising public awareness of health consequences [21].

## CONTRIBUTION

The authors were equally involved in writing the manuscript and are equally responsible for plagiarism.

## CONFLICT OF INTEREST

The authors declare no conflict of interests regarding the publication of this article.

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