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Mercury intake via consumption of imported Atlantic mackerel (*Scomber scombrus*) in Istanbul

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Abstract

The aims of this study were to determine the concentrations of mercury (Hg) in frozen imported Atlantic mackerel consumed in Istanbul and to predict their potential health consequences. In this study, the concentration of Hg was determined following US EPA Method 7473 (2007) using a direct mercury analyzer (DMA-1). Mercury level of the Atlantic mackerel ranged between 0.045 to 0.065 mg/kg. The mercury levels were well below the limit value of 1.00 mg/kg wet weight (EC, 2006; Turkish Food Codex, 2011) for fish such as mackerel. The potential human health risks of Atlantic mackerel sold in Istanbul were also assessed in terms of Hg levels. The estimated weekly intakes (EWI) of the mercury were lower than established provisional tolerable weekly intakes (PTWI). Target hazard quotient (THQ) values were below 1, indicating that Atlantic mackerel consumption is not a potential health risk in adults and children. According to the amount of Hg, this fish can be consumed safely 3 times a week. Furthermore, it is determined that consumption of fish from the IV. Region 4 times a week will not be a problem because of the low amount of Hg. Our results provide a good tool to determine the Hg exposure of Turkish consumers (adult and children) via Atlantic mackerel consumption in terms of food monitoring and food safety.

Keywords: Mercury, *Scomber scombrus*, Health risk, PTWI, THQ

Introduction

Fish is an important source of proteins, aminoacids, fatty acids, vitamins and minerals, which are necessary elements for human diet (FAO, 2020). In addition, Omega-3 fatty acids in fish have been reported to reduce the incidence of heart disease and stroke (Ababneh, 2013). In addition to the good benefits of fish, fish may contain some toxic contaminants, which are of significant concern because of their potential adverse effects on human health (Visciano et al., 2014). The heavy metals released into the environment have created an environmental problem in the world. Toxic metals are important water pollutants due to their toxicity, long-term environmental stability and bioaccumulation properties (Guerin et al., 2011). Mercury is classified as a toxic heavy metal and its presence in food is limited by law, considering human health (Visciano et al., 2014). The environmental risk of Hg is very high since it can be volatile and transported over long distances in the atmosphere (Ordiano-Flores et al., 2012). Once Hg entered the marine environment as a result of environmental pollution such as transportation, agriculture, industry and urbanization, it can accumulate in trophic level (Gorur et al., 2012). Its organic compounds are the most toxic forms, particularly methylmercury (Ikem and Egiebo, 2005). Organic mercury is absorbed more easily by fish, so that methyl mercury enters the food chain through fish consumption (Agusa et al., 2005; Kibria, 2016). Fish has good health effects due to PUFAs, but methyl mercury may inhibit their efficiency. It causes significant behavioral disorders in children, damaging the developing fetus and young children (Guallar et al., 2002; JECFA, 2007). Fish is the main way of human exposure to Hg. Therefore, the

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maximum mercury concentration that can be found in fish in terms of human health is limited by law. It was generally concluded that if the maximum Hg level in fish muscle exceed the permitted limit value, consuming contaminated fish may lead to adverse health effects on human. However, as much as the amount of Hg in fish, the amount of fish consumed by human is also important in terms of potential health risk. The risk assessment based on the target hazard coefficient (THQ) indicates the potential health risks from dietary metal intake (Burger, 2009; Kral et al., 2017).

Atlantic mackerel is a great source of omega-3 polyunsaturated fatty acids (PUFAs), which makes it an excellent food for nutrition (Romotowska et al., 2016). Frozen imported Atlantic mackerel (*Scomber scombrus*) is an important food fish in the diet of Turkish consumers. In recent years, consumption of imported mackerel from Norway has increased considerably in Turkey. According to the Norwegian Seafood Council, Turkey is the sixth country that imports most frozen mackerel from Norway in 2016 (Statista, 2018). Imported mackerel can be consumed over the year, independently from the closed fishing season implemented in Turkey. Besides, its desirable taste appreciated by Turkish people, its price also is affordable. So, consumption of this fish has increased in this country. Unfortunately, there is limited information on mercury level in imported frozen Atlantic mackerel sold in our country. According to the table of mercury levels in commercial fish and shellfish (1990-2012), prepared by FDA (2017), Northern Atlantic mackerel contains low levels of Hg. However, this list was prepared according to the data of NMFS REPORT 1978. Since it is known that mercury levels in fish can vary significantly over the years due to pollution and environmental factors; monitoring the current status of commercial Atlantic mackerel in terms of mercury content and potential risks is important for international trade and human health.

Atlantic mackerel is a pelagic carnivorous fish (Luna, 2019). Mercury distribution in the fish depends on the age, maturation status and habitat of the fish. It is stated that the main way of mercury intake of fish is the diet, and differences in the feeding ecology of such fish affects the accumulation of Hg (Bae et al., 2011; Barone et al., 2015). Daily industrial, agricultural and domestic human activities contribute to accumulation of mercury in the ecosystem (Abubabakar et al., 2015), and there may be potential risks due to heavy metal uptake changes. Although there are few studies on Hg concentrations in Atlantic mackerel, no study focused to the Estimated Weekly Intakes (EWI), Provisional Tolerable Weekly Intakes (PTWI), Hazard Index (HI) and the Target Hazard Quotient (THQ). Thus, it is very important to determine of potential risks related to Hg concentrations in Atlantic mackerel which constitutes a large percentage of imported fish consumed in the world.

In this study, Hg levels in the edible tissues of frozen Atlantic mackerel (*Scomber scombrus*) sold in the local fish markets in Istanbul were determined and dietary intakes of Hg were assessed. The health risk of Atlantic mackerel was evaluated by calculating EWI, PTWI, HI and THQ values according to Turkish consumers. The aims of this work were to determine the concentrations of Hg in frozen imported Atlantic mackerel consumed in Istanbul and to predict their potential health consequences.

Materials and Methods

Samples

Atlantic mackerel samples were obtained from local fish markets located in five main regions (Region I= Eminonu, Region II=Uskudar, Region III= Kadıkoy, Region IV= Karakoy and Region V=Beyoglu) of Istanbul (Fig 1). Sampling (n=15) was carried out in these markets during spring season, 2018. According to the label information of the batches, Atlantic mackerels were caught from the Atlantic, Northeast (FAO 27). These samples were produced in Norway and the production time of them varied between 20.10.2018-05.09.2018.

Figure 1. The locations of sampled local fish markets.

Norwegian mackerels can be caught from different catching areas in different seasons; stored as frozen, then can be exported. They can also be marketed in Istanbul at different times. This is the reason of our sampling from various regions of Istanbul. Istanbul, with a population of 15.067 724, represents a significant part of the Turkish population, since it is an immigration megapol of Turkey (Istanbul Governorship, 2018). Density of the population and the performance of trade are the reasons for choosing this city as the study area. The average lengths of samples were 32 ±1.32; 31.43 ±0.12; 31.50 ±0.50; 31.00 ±1.00 and 31.67 ±1.53 while the average weights were 422.59 ±77.41; 408.68 ±10.64; 412.63 ±4.65; 385.17 ±31.00 and 381.67 ±24.01 for Region I, II, III, IV and V, respectively. Each individual of fish was analyzed for Hg concentrations.

Mercury analysis

The concentration of Hg was determined following US EPA Method 7473 (2007) using a direct mercury analyzer (DMA-1; Milestone SRL, Sarisole BG, Italy). The method is based on the thermal decomposition of sample, mercury amalgamation and atomic absorption detection. Each fish sample was weighed (0.1 g) into a quartz tube, then, the tubes were placed into the auto injector. The samples were heated with oxygen stream passing over them at 650 °C. The mercury vapor was mounted on a gold coupling trap and then quantitatively decoded. The Hg content was determined using atomic absorption spectrometry at 254 nm, and the results were calculated using DMA-1 PC software. The operating times in the study were 1, 2 and 1 min, respectively for drying, combustion, and post-combustion flushing periods. Total analysis time per sample was less than 10 minutes. The DMA-1 was calibrated using the certified reference material (fish muscle (Catalogue No. ERM-BB422, the Joint Research Centre (JRC), Italy). The results were determined in mg/kg wet weight. All analyses were in triplicate, the mean values and standard deviations were calculated.

Health risk assessment

The estimated weekly intake (EWI) value in µg/kg body weight was determined by multiplying the mean concentration of Hg (µg/g) with the amount of weekly consumed fish, and divided by the average value of children and adult body weights (14.5 and 70 kg) (Hajeb et al., 2009; US EPA, 2000).

EWI= [WFC X C] / BW

In Turkey, weekly fish consumption (WFC) amounts for adults and children are 106 g and 50 g, respectively (Fisheries Statistics, 2018). C is the mean concentration of Hg (µg/g) and BW is the average body weight. The provisional tolerable weekly intake (PTWI) values were multiplied by the average children and adult body weights. Then, the percent PTWI was calculated (EFSA, 2012).

PTWI=PTWI (supplied for each metal) x BW

Target hazard quotient (THQ) values indicate health risks to humans via dietary intake of fish because of heavy metal exposure. The THQ, expressing the risk of noncarcinogenic effects, is the ratio between exposure and the oral reference dose (RfD). If the ratio is less than 1, therefore, it seems to be carry no obvious health risk. Conversely, if the dose is equal to or greater than 1, the RfD (Yi et al., 2011), an exposed population will experience health risks (Pazi et al., 2017). In this study, health risks through Atlantic mackerel consumption in Turkey were examined based on THQ values. The dose calculations in the method of determining the THQ value were provided in the US EPA Regional Screening Levels Generic Tables (US EPA, 2018) and THQ values were calculated according to the following formula (Ihedioha and Okoye, 2013):

$(E_{Fr} \times E_D \times F_{IR} \times C) / (R_{FD} \times W_{AB} \times T_A)] \times 10^{-3}$,

where EFr is the exposure frequency (350 days/year); ED is exposure duration, total (70 years for adults; 6 years for children); F_{IR} is the food ingestion rate (15.07 and 7.14 g/person/day for adult and children Turkish consumers, respectively; C is metal concentration (µg/g); R_{FD} is the oral reference dose (mg/kg/day); W_{AB} is the average body weight (70 kg for adults, 14.5 kg for children), T_A is averaging time for non-carcinogens (365 days/year x ED).

An allowable fish consumption (CR_{lim}) rate for a noncarcinogen can be calculated with the following formula and is expressed in kilograms of fish per day (kg/d) (US EPA, 2000):

$CR_{lim} = R_{FD} \times BW/ C_m$

where R_{FD} is for methylmercury 1.0×10^{-4} mg/kg/day (ATSDR, 2009); BW (consumer body weight) is 70 and 14.5 kg for adults and children, respectively; C_m is measured concentration of chemical contaminant in a given species of fish (mg/kg).

Statistical analysis

Statistical analysis was performed with SPSS 21.0 (SPSS Inc. Chicago, IL). Data were analyzed by one-way ANOVA, and Tukey test were applied for multiple comparison. Statistical significance was expressed at $p < 0.05$.

Results and Discussion

Observed and certified values (mg/kg) were shown in Table 1. The mean concentrations of Hg were 0.056 ±0.01, 0.063 ±0.02, 0.057 ±0.00, 0.045 ±0.01 and 0.059 ±0.01 mg/kg for Region I, II, III, IV, V, respectively (Fig 2). EWI and PTWI values for adults and children were presented in Table 2 while THQ and CR_{lim} values for adults and children were given in Table 3.

Table 1. Observed and certified values (mg/kg) of mercury concentrations in standard reference material (dry weight) (n=3)

	Certified value	Uncertainty	Observed value	Recovery (%)
Hg	0.601	0.030	0.645 ±0.040	107.32

In our study, there were no significant differences ($p > 0.05$) between Hg concentrations of fish, obtained from different regions of Istanbul. Alcala-Orozco et al. (2018) also showed similar finding to our study. In general, the permitted limit for Hg in fish is 0.50 mg/kg, but this limit is 1.00 mg/kg for the species such as mackerel (EC, 2006; Turkish Food Codex, 2011). The highest mean concentration of Hg was found as 0.063 mg/kg for Region II (Figure 2), and the mercury concentrations of all samples were well below the limit value of 1.00 mg/kg wet weight. Tuzen (2009) reported Hg concentration in Atlantic mackerel (*Scomber scombrus*) as 0.06 mg/kg. Likewise, Visciano et al. (2014) reported the concentrations of Hg for Atlantic mackerel samples below 1 mg/kg. Łuczyńska and Krupowski (2001) stated that the contents of Hg in *Scomber scombrus* bought from supermarkets of Olsztyn, Poland ranged between 0.039–0.068 mg/kg (mean 0.052 mg/kg). In addition, Kral et al. (2017) and Mol (2011) found that average concentrations of total mercury (mg/kg) lower than the legal limit (1.00 mg/kg) for canned mackerel. The value of Hg in frozen Atlantic mackerel purchased from the Jagalchi fish market of Korea was found to be 0.08 mg/kg (Bae et al., 2011). Likewise, total Hg content in mackerel from Malaysia (Hajeb et al. 2010), Italy (Plessi et al., 2001; Storelli et al., 1998), and Croatia (Juresa and Blanusa, 2003) reported below 1 mg/kg. These results are similar to our findings. However, Abubakar ve et al. (2015) reported Hg concentrations in frozen *Scomber scombrus* above the permitted limits and suggested periodical monitoring regarding human health risks.

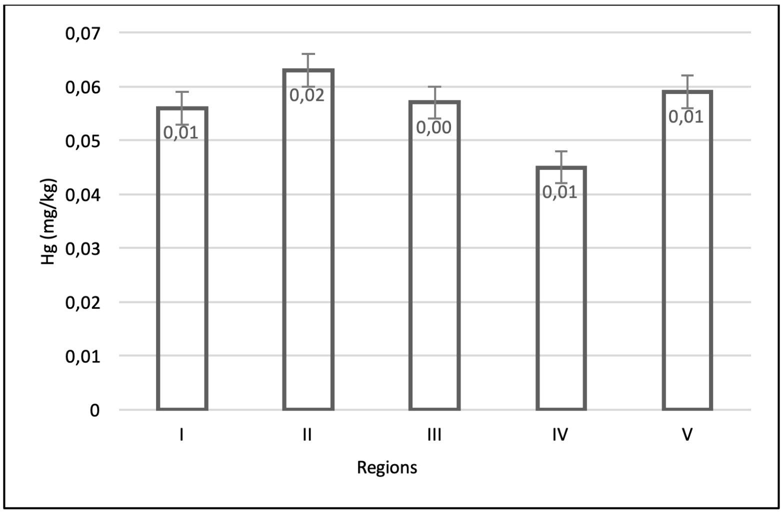

Figure 2. Mean concentrations of Hg (mg/kg wet weight) in Atlantic mackerel samples of different regions.

Table 2. Estimated weekly intakes (EWI) and percent PTWI's for Atlantic mackerel, consumed by children and adults

PTWI (µg Hg /week/kg body weight)	PTWI* (%) Adult	PTWI** (%) Child	Adult		Children	
Regions			EWI	PTWI (%)	EWI	PTWI (%)
1.6[a]	112	23.2				
I			0.08	5.29	0.19	12.05
II			0.10	5.99	0.22	13.64
III			0.09	5.41	0.20	12.33
IV			0.07	4.26	0.16	9.71
V			0.09	5.59	0.20	12.72

*PTWI for a 70 kg adult (µg/week body weight)

** PTWI for a 14.5 kg child (µg/week body weight)

a EFSA, 2012

The PTWI values for adults and children were calculated and compared with EWI values (Table 3).

The estimated weekly intake (EWI) values of Hg in our study were ranged between 0.07- 0.10 µg/kg bw/week for adults, and 0.16- 0.22 µg/kg bw/week for the children. Even though EWI of young's were higher than that of adults; it was still very far from indicating a potential risk, due to consumption of Atlantic mackerel. The established PTWI values (µg/week/kg) were proposed as 1.6 for Hg (EFSA, 2012). In this study, the average adult and child body weight were considered as 70 and 14.5 kg, respectively. The results indicated that the EWIs of total mercury were below the respective PTWI (Provisional tolerable weekly_intakes) (µg/kg/week) recommended by EFSA (2012). A potential risk has been notified when the percent PTWI is above 100 % (Mol et al., 2019). So, average Turkish adult and young population, consuming frozen Atlantic mackerel, does not have a health risk in terms of mercury. Likewise, Llull et al. (2017) reported the estimated weekly intakes (EWI) in children (7–12 years of age, 34.48 µg/kg body weight) and adults (>17 years of age, 68.48 µg/kg body weight) below the provisional tolerable weekly intake (PTWI) of Hg established by EFSA in 32 fish species from the Balearic Islands._Similarly, the EWI of total mercury in grey mullet from The Caspian Sea was below the respective PTWI for an adult (70 kg) (Hosseini et al., 2013). However, the absence of risk for the average consumer does not mean that there is no risk for the heavy consumers (Guerin et al., 2011). Olmedo et al. (2013) reported that there is no risk of heavy metal in some shark species. However, they emphasized the possibility of health risk in over-consumption of these species. But at the same time they highlighted the possibility of health risk for heavy consumers on account of excessive shark consumption. Akhbarizadeh et al. (2018) found that Hg weekly intakes for adults below the reference values in fish species caught from the northeast Persian Gulf. But, they stated that children under 16 kg should have less than 50 g of meal size. In addition, Hajeb et al. (2009) found that the EWI values were below the respective PTWI for in mackerel from fish markets in Malaysian, and also underlined that the large consumption pattern for mackerel may increase health risks in terms of especially pregnant women and children._

Table 3. Estimated Target Hazard Quotients (THQs) and cancer risk (CR_{lim}) for Hg caused by consuming Atlantic mackerel for children and adults.

CR_{lim} (g/day) / CR_{lim} (meals per week)		THQ	
Children	Adults	Children	Adults
26 / 3	125 / 3	0.34	0.12
23 / 3	111 / 3	0.39	0.14
25 /3	122 / 3	0.35	0.12
32 /4	155 / 4	0.28	0.10
25 /3	119 / 3	0.36	0.13

The THQ was used to express the potential health risks of adult and young Turkish people, consuming Atlantic mackerel. If the ratio is less than 1, potential risk is not concerned. This level of exposure is thought to be insignificant enough to have no negative effect during a person's lifetime (Yi et al., 2011). In the present study, the THQs values for Hg via Atlantic mackerel consumption were determined well below 1 for adults and children (Table 3). It shows that exposure to Hg via imported Atlantic mackerel consumption do not pose a significant health risk for children and adults. Yi et al. (2011) studied the health risks of heavy metals to the general population and fisherman in Yangtze River, China. Likewise, they reported THQ values for all species below 1, but emphasized health risks associated with fish consumption should be controlled regularly.

CR_{lim} is the maximum allowable consumption rate without adverse health effects. Therefore, to determine the allowable fish consumption (daily or weekly) is very important for human health (Hosseini et al., 2013). In this study, the allowable fish consumption rates were determined according to adults and children for all regions (Table 3). The standard portion amount of raw fish consumed by an average adult and child are 227 g and 48 g, respectively according to US EPA (2000). The average body weights of Turkish adults and children assumed to be 70 and 14.5 kg, respectively. According to the amount of Hg, this fish can be consumed safely 3 times a week. Furthermore, it is determined that consumption of fish from the IV. Region 4 times a week will not be a problem because of the low amount of Hg. According to weight of adult and children, the consumption rates and the number of meals can be proportionally higher or lower, respectively. Hosseini et al. (2013) calculated CR_{lim} and the permissible amount of grey mullet from the Caspian Sea in terms of mercury intake, using the same method. They reported allowable consumption rate as 51 g, and concluded that is not a serious threat for Iranian consumers. Asare-Donkor and Adimado (2016) evaluated the concentrations of the total mercury in fish from the Ankobra and Tano River basins in South Western Ghana, and estimated the THQs, allowable consumption rate and EDI values with regard to human health. They emphasized that these values should be carefully monitored and controlled to reduce the potential health risks of Hg levels. Alcala-Orozco et al. (2017) studied Hg concentrations in canned tuna sold in Colombia and estimated maximum allowable tuna consumption rate in meals/week (CR_{mw}) regarding human exposure. They resulted that the consumption of canned tuna may pose a high risk to the people of Colombia. Moreover, Olivero-Verbel et al. (2016) assessed the levels of Hg in fish in the Caqueta River, at the Colombian Amazon, as well as to determine fish consumption-based risks (CR_{mw}, THQ), but THQS values were so high than our results, and CR_{mw} indicated that Hg concentrations are limited to two meals a week, recommending these fish species may be risky for consumer health revealed. Pal and Maiti (2017) evaluated health risks of the heavy metal pollution in cultured fish from Urban Aquaculture Pond, India in case of children and adults, and THQs values were higher than our results.

Conclusions

The frozen Atlantic mackerel is one of the most commercially valuable fish species in European countries. Also, it is considerably important food source, commonly consumed all over the world. In the present study, it was determined that estimated weekly intakes (EWI) of mercury via consumption of Atlantic mackerel were far below the established provisional tolerable weekly intake (PTWI) values recommended by EU (2006) in case of adult and children. The THQ values were below 1, indicated no potential health risk in adult and children with consumption of Atlantic mackerel. Considering the Hg concentrations in Atlantic mackerel the allowable fish consumption rate for adults and children is recommended as 3 meals per week. More than this, 4 meals of fish per week may be allowable for this species having low Hg content, obtained from some regions. Therefore, it is concluded that the consumption of Atlantic mackerel, which sold in Istanbul local fish markets, posed no health risk to the consumer on the basis of adult and children in our society. Our results provide a good tool to determine the Hg exposure of adult and children via Atlantic mackerel consumption in terms of food monitoring and food safety. At the same time, these results showed useful data for the unfounded news about the mercury content of frozen Atlantic mackerel in Turkey.

Compliance with Ethical Standards

Conflict of interest

The authors declare that for this article they have no actual, potential or perceived the conflict of interests.

Author contribution

The contribution of the authors is equal. All the authors read and approved the final manuscript. All the authors verify that the Text, Figures, and Tables are original and that they have not been published before.

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