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Mercury Concentration of Muscle Tissue and Relationship with Size of Yellowfin Tuna, *Thunnus albacares*, of the Indian Ocean

B.K.K.K. Jinadasa[1]*, G.D.T.M. Jayasinghe[1], E.M.R.K.B. Edirisinghe[2] and I. Wickramasinghe[3]

[1]Analytical Chemistry Laboratory (ACL), Institute of Post-Harvest Technology (IPHT), National Aquatic Resources Research and Development Agency (NARA), Crow Island, Colombo-15, Sri Lanka

jinadasa76@gmail.com, thilini.madurangika123@gmail.com

[2] Department of chemical sciences, Faculty of Applied Sciences, Rajarata University of Sri Lanka, Mihintale, Sri Lanka

ranjith_e@hotmail.com

[3]Department of Food Science and Technology, Faculty of Applied Sciences, University of Sri Jayewardenepura, Nugegoda, Sri Lanka

indiraw2002@yahoo.com

Abstract: Mercury (Hg) is a naturally occurring metal in the earth's crust and can enter the aquatic environment through natural and anthropogenic activities. Part of Hg is converted to methyl-mercury (MeHg) and accumulates in fish through the food chain reaching its highest levels in large predatory fish such as tuna. Consumption of contaminated fish has been considered a serious public health concern. Yellow fin tuna (*Thunnus albacares,* YFT) comprises the most important component of the Indian Ocean tuna catches and it can contain significant levels of MeHg. For better understanding and monitoring purpose of Hg levels in YFT populations, total Hg (T-Hg) concentrations were analyzed in edible muscle tissue from 140 YFT collected from major fish landing sites of Sri Lanka in 2010 and 2011. The samples were analyzed using cold vapour atomic absorption spectrophotometric method, with microwave assisted digestion. In Sri Lankan waters, Hg levels in YFT ranged from <LOD (0.021) to 0.98 mg/kg (mean ± SD = 0.30±0.18 mg/kg; median = 0.27 mg/kg) in wet weight basis. Data from the present study suggest that Sri Lankan YFT contain lower levels of Hg compared with the EU/EC recommendations (1 mg/kg). T-Hg levels of YFT were positively related with fish length and weight.

Keywords: Total mercury, Yellowfin tuna, Indian Ocean, Sri Lanka

1. Introduction

Fish and seafood products are nutrient-rich foods containing proteins, omega 3 fatty acids, vitamins, minerals etc. It's associated with various beneficial health effects and regarded as an important component of a healthy diet. Food based nutritional guidelines of many countries, including Sri Lanka; recommend the increased intake of fish and seafood. The fish consumption per capita (including dried fish and canned fish) is 15.3 kg/year, but Medical Research Institute (MRI) of Sri Lanka recommends the increase in the per capita consumption of fish up to 21 kg/year for a healthy population [1]. However, some fish species can also contain harmful substance such as persistent organic pollutants (POPs),polychlorinated biphenyls (PCBs), dioxins, furans and other environmental contaminants such as mercury, cadmium and lead[2-5]. These contaminants are present at low levels in water systems, but bio-concentrate from one trophic level to another and reaching their highest levels in large and old predatory fish species and marine mammals [3, 6].

Corresponding Author: B.K.K.K. Jinadasa

Mercury is a naturally occurring trace metal that is present in air, water and soil. It is an environmental pollutant that exists in several forms: elemental or metallic mercury, inorganic mercury and organic mercury. Elemental mercury has long been used in thermometers, mirrors and first aid kits. The amalgam used in dental fillings, consisting of about 50% mercury, is an example of a metallic mercury compound. Organic mercury is found mainly in fish and seafood as methylmercury species such as CH_3Hg^+this is the most toxic forms of Hg and have received considerable attention in the world[5, 7]. Mercury contamination varies by fish species and cannot be removed through the trimming, skinning and cooking process, because MeHg binds to proteins in the muscle tissue of fish rather than to fatty deposits[8, 9].The urine and faeces are the main excretory pathways of the elemental and inorganic Hg forms from the body with a half-life of approximately 1-2 months (WHO, 2003). Regular consumption of seafood may result in the accumulation of mercury in the body, especially when the rate of consumption exceeds the rate at which the body eliminates it. Exposure to high amounts MeHg can damage the central nervous systems (CNS), and the developing brains of young children and the foetus (WHO, 2003).

The food safety issues concerning Hg are managed by both advising on intake levels through the provisional tolerable weekly intake (PTWI) level and setting actual upper limits in foods. At present, the European Union (EU) has set an upper limit of Hg 1 mg/kg wet weight (ww) basis [10] for YFT. Public healths regulations in the USA also prohibit consumption of fish with fillet Hg concentrations of more than 1 mg/kg, ww. In 1972, FAO/WHO joint expert committee on food additives (JECFA) has set a PTWI value for Hg for human sat 5 µg/kg body weight [11].

Yellowfin tuna (YFT, *Thunnus albacares)* is one of the main target species of the commercial tuna fisheries in Sri Lanka and has a long history of scientific research. YFT often marketed as Ahi, belongs to the family scombridae and known as a highly migratory fish species.YFT is a one of the largest tuna fish species found in tropical and subtropical oceanic areas from worldwide oceans excluding Arctic Ocean[12]. YFT is preferred to leave mixed surface layer, which above the thermocline as well as contribute a large proportion of the world fishery. Sri Lanka is one of the oldest and most important YFT producing countries in the Indian Ocean [13, 14].In 2010, it was reported that the total catch of YFT was 45,650 metric tonnes, meanwhile 1535 metric tonnes t was exported[15].

The objective of this study was the determination of the total Hg concentration of edible muscle of YFT and find out the correlation the Hg concentration with length and weight of YFT.

2. Materials and Methods:

Between July 2010 and March 2011, 140 YFT was sampled from the fish landing site; Trincomally, Beruwala, Galle and Modara fisheries harbours of Sri Lanka (Fig. 1). These four fisheries harbours cover most important landing places specially operating high numbers of multi day fishing boats. The 500 g of edible muscle samples was taken from near the dorsal fin area of each fish, then immediately packed and iced. The total weight and total length of fish were recorded. The filleted samples were transported to the Analytical Chemical Laboratory, National Aquatic Resources Research and Development Agency (NARA) and store -20°C until further analysis

Fig. 1. Map of Sri Lanka showing the positions of sampled

All chemicals, including standard were analytical reagent (AR) quality or better and purchased from Sigma and Fluka chemicals, Switzerland. De-ionized water (>18.2 MΩ/cm) was used throughout the work. The all glassware and plastic ware were used first soak overnight in a liquid detergent solution in tap water. The glass/plastic ware then thoroughly rinse with tap water and then soaking 10% (v/v) HNO_3 overnight. Subsequent rinsing was performed using de-ionized water. Then glassware was oven dried and plastic ware was air dried prior to use.

A Varian 240 FS Atomic Absorption Spectrophotometer instrument (Varian, Springvale, Australia) equipped with and Cold Vapor Generation Accessory; VGA-77 was used for the Hg determination. For microwave assisted wet digestion, MASS 1500+ microwave system (CEM, Matthews, North Carolina, USA) was used.

For determination of Hg, the thawed samples of 1 g wet weight were submitted to microwave assisted wet digestion using 10 mL concentrated nitric acid in the MASS XP 1500+ microwave system with a following program (1400 W, ramp time 15 min, 800 PSI, 200°C and holding time 10 min). The digests were diluted to a final volume of 50 mL with de-ionized water. Freshly prepared Hg standard solution (1 mL/L) was made by appropriate dilution and used for prepared working standard solution. A $SnCl_2$ solution was used as the reductant and distilled water used as an acid solution to cold vapour VGA-AAS. Blanks, samples and quality control samples were analysed following the same procedure. The Hg was assessed for compliance with the methods performance criteria guideline published by the EU, 2001/22/EC. Average recovery, precision, specificity, the detection limit and accuracy in the test were good agreement with the requirement. The trueness of Hg determination was evaluated by the analysis of the standard quality control sample, canned fish muscle T/0774 from Food Analysis Performance Assessment Scheme (Fapas), UK (n=10, certified value = 19.9 mg/kg, recovery was 98.9%) and meanwhile participated proficiency testing program with Fapas, were used for quality control of study (canned fish, 07115/2009, Z=0. 1). The Limit of Detection (LOD = mean blank + 3s) and Limit of quantification (LOQ =3 x LOD) for Hg was estimated from the blank measurements according to EURACHEM, and the value was 0.007 mg/kg and 0.021 mg/kg respectively.

The statistical analysis was performed using Microsoft Excel, 2011, SPSS (Statistical Package for Social Sciences) 16 and Curve Expert Professional software.

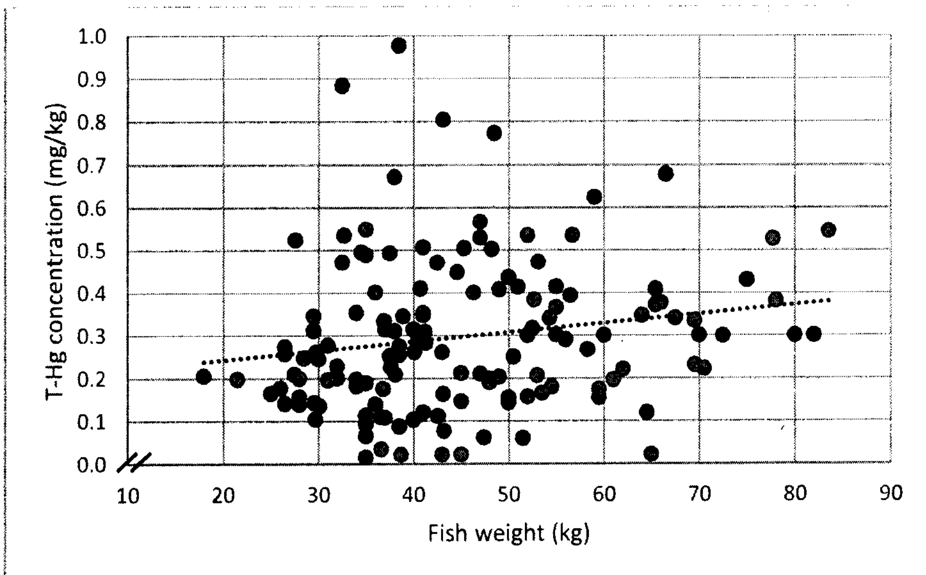
3. Results and Discussion:

This study provides information on T-Hg levels in the muscle tissue of YFT collected from the landing sites of Sri Lanka, and also examines the relationship between T-Hg concentration with length and weight of fish. A total of 140 YFT were analysed and results are given in table 1.

Table 1: Length, weight measurement and mercury content of 140 samples of YFT

	Weight (kg)	Length (cm)	T-Hg (mg/kg), w/w
Avg. ± SD	45.28 ± 13.96	123.4 ± 23.8	0.30 ± 0.18
Range	18.00 – 83.50	64.0 - 173.0	<LOD (0.021) – 0.98

Figure 2 shows the correlations between YFT weight, length and T-Hg content. There is a positive correlation with weight of fish (R^2=0.24, r=0.53) for larger fish to have a higher Hg content. The model fit is linear one in which Y= a + bX where a = 0.9688, b= 3.742 and standard error was 0.09. This slight correlation is also shown in Figure 2 with the correlation between YFT length and T-Hg content (R^2=0.15, r=0.41) which is a linear model fit. The model values were; a = -5.976, b = 2.463 and standard error = 0.152. The linear relationship between age or size of many carnivore species and Hg concentration is well documented and this study also confirms that. By the calculation of linear regression equation, it was found that, the Hg levels in YFT weighing more than 249 kg or above length of 408 cm, exceed the 1.0 mg/kg level. Nevertheless, YFT of such length and weight was not recorded during the present study.



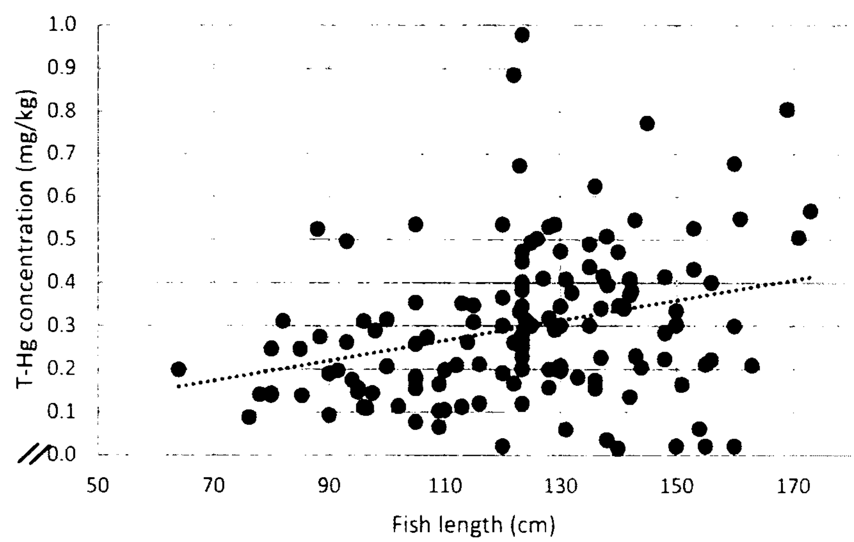


Fig. 2: Correlation between weight, length and mercury concentration of YFT in the present study

In comparison with published data, the Hg levels detected in YFT during this study were quite similar to YFT from oceans around the world as shown in table 2.

Table 2: T-Hg (mean and range) of YFT recorded in other studies

T-Hg (mg/kg)	T-Hg range (mg/kg)	Area	Reference
	0.026-0.234	Andaman Sea	[16]
0.25	0.068-0.650	Florida Atlantic coast	[17]
0.092	0.061-0.124	Bay of Bengal	[18]
0.21	_	Pacific ocean	[19]
0.13	_	Mozambique Channel	[20]
0.21	_	Reunion Island	[20]
0.54	0.24-1.32	Hawaii	[21]
0.42	0.07-1.20	Gulf of Guinea	[21]
0.05	0.01-0.08	West coast, Sri Lanka	[22]
0.30	<0.021-0.98	Indian Ocean, around Sri Lanka	This study

Research and monitoring of the bio-geochemical cycle of Hg in the marine environment is critical to expanding the current understanding of the Hg sources that contaminated the fish. Limited information exists regarding T-Hg in YFT from the Indian Ocean around Sri Lanka. In an earlier study by Senadheera, 2005, 40 muscle samples of YFT collected from the west coast in Sri Lanka were analysed. It is not clear if the total length of the fish was studied, but the mean weight was 48 kg. T-Hg of these fish ranged from 0.01-0.08 mg/kg in wet weight basis. The mean T-Hg value of that study (0.05 mg/kg) and the range of Hg concentration were lower than those observed in this study, but sampling procedure and analytical method used in the two studies may not be directly comparable. For that study, the samples were collected from a local fisherman on the west coast and from fish export factory, as well as for Hg analyses was performed by the colorimetric dithizone method described in Association of Analytical Communities (Association of Official Analytical Chemists, AOAC) 952.14.

Several factors are likely to be responsible for the observed differences in T-Hg levels in YFT. For marine fishes, dietary exposure, size and age of fish and trophic levels are "important sources of T-Hg" (Joanna and Michael, 2006 and Wang, 2002).Other factors are temperature, salinity, pollution sources, sexual state, feeding mechanisms and physiological state of the animals [23].In generally larger fish contain higher T-Hg concentrations than smaller fish within the species[24]. Fish are in a higher position in the aquatic food web and therefore they accumulate more biomagnifying contaminants such as Hg [25]. YFT principally consumes a variety of crustaceans and squids (www.fishbase.org). YFT is classified as a highly migratory fish species by FAO 1997, and the difference of T-Hg may be prey available during the migration. Information regarding the age and growth of YFT in Indian Ocean surrounding Sri Lanka is limited, and specific age of species in this study has not been determined. The preliminary estimate of the age of YFT from this study based on length and weight data from other regions, indicate that of fish samples are between 1.5 and 4+ years old. The mean growth rate of the YFT in Indian Ocean was approximately 1-2 mm/day [26].

Fish and seafood are highly regarded as rich in nutrition, especially protein, omega 3 fatty acids, vitamins and minerals, thus challenges still remain with regard to balancing risk benefit messages regarding fish consumption and Hg. Predatory marine fish species, especially in upper trophic levels, such as YFT can accumulate relatively high levels of Hg. The nature of bioaccumulation of methyl Hg based on several factors including multiple anthropogenic and natural sources. Methyl Hg exposure through fish consumption will continue to remain as a public health concern. The consumption of fish and fishery products is the main pathway for human exposure to Hg [2].Thus, protection of public health is generally states responsibly, and preventive action should be taken into consideration to minimise the risk to the human health. Many states and national and international organization handle this responsibility by issuing consumer guides or regulations. Based on the recently issued consumer advisories from United States Food and Drug Administration (FDA) on Hg in fish, it has been suggested the pregnant women, lactating women and women who wish to become pregnant should avoid eating some fish species. For pregnant women it may be prudent to avoid any fish with maximum mercury concentrations greater than 0.3 mg/kg[24]. The EU also issued guidelines for setting maximum levels of contaminants in fish [10], which state that the maximum allowable level of T-Hg in YFT as 1 mg/kg. Based on these guidelines Sri Lanka also established the maximum allowable level of Hg in fish, but this covered only the export fish sector and, not the local consumption[27].

4. Conclusions

It can be concluded that the T-Hg content of the Indian Ocean around Sri Lanka, as reported in this study are well bellowed EU/EC regulation tolerance limits of 1.0 mg/kg. It is recommended that population groups at risk in Sri Lanka should limit consumption of YFT and consumption of large YFT should be avoided.

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