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Mercury Levels of Seafood Commonly Consumed in Taiwan

Y. C. CHEN^{1,2} AND M. H. CHEN^{2*}

¹. Department of Food Nutrition, Chung Hwa College of Medical Technology, Jen-Te Hsiang, Tainan 717, Taiwan, R.O.C.

². Department of Marine Biotechnology and Resources, National Sun Yat-sen University, Kaohsiung City 80424, Taiwan, R.O.C.

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ABSTRACT

In this study, the mercury level in 25 commonly consumed seafood species was identified and used to evaluate the mercury intake for Taiwan population. Total mercury concentrations were determined by using furnace-gold amalgamation mercury analyzer. The results indicated that mercury concentrations of the 25 seafood species ranged from 0.002 to 0.198 mg/kg wet wt. and varied significantly across species ($p < 0.05$). All mercury concentrations of the 25 seafood species were below the safety standards, 0.5 mg/kg, set by TWDOH, EC and FAO/WHO. Mercury intake from seafood consumption for female and male adults in Taiwan was estimated to be 21 and 30 $\mu\text{g}/\text{week}$, respectively, which was well below the PTWI. Among the seafood items tested, fish was the major source of total mercury intake for Taiwan population (74-83%). The marine fish contributed the most, followed by shellfish and freshwater fish. The highest mercury level was found in tuna. The mercury intake could be within the PTWI if general population weighted 65 kg consumed daily 90 g of seafood with mercury concentration as 0.17 mg/kg.

Key words: mercury concentration, fish, shellfish, food safety

INTRODUCTION

Mercury, a highly toxic substance, occurs in the nature environment. It can be released into the air as a result of human or volcanic activities and then transported globally via air circulation. The mercury in the atmosphere was returned into soil and oceans via wet precipitation. Mason *et al.*⁽¹⁾ estimated that over the last century anthropogenic emissions have tripled the concentrations of Hg in the atmosphere and in the surface ocean. Due to the bioaccumulation character, mercury, particularly methylmercury, has the tendency of magnification in the food chain⁽²⁾. Therefore, the mercury in the edible marine organism in the marine food chain can be transferred into human bodies⁽²⁾.

To the general public, food consumption was the main source of mercury exposure⁽³⁻⁵⁾. In Spain, Finland and Japan, studies revealed that fishermen and seafood-lovers who consumed seafood more had higher mercury intake and higher mercury level in their tissues than the general public and vegetarians⁽⁵⁻⁸⁾. That indicates that seafood consumption is related to mercury intake. The greater the seafood consumed, the higher the mercury intake is⁽⁹⁾. Excessive mercury intake may cause the permanent harm to the central nervous system⁽¹⁰⁻¹¹⁾, such as behavioral disorders and deficiencies in immune system and development^(4,7,11-12).

Surrounded by the ocean, Taiwan is abundant in seafood, which is easy to acquire as the source of protein in diet⁽¹³⁾. In the past, due to the limitation of instrumental sensitivity of mercury analysis, the studies regarding mercury levels in the seafood were rare. Therefore, the risk of dietary mercury intake in Taiwan was uncertain. The purpose of the study is to determine the mercury levels

in seafood and assess the risk of the mercury intake from seafood consumption for Taiwan residents.

MATERIALS AND METHODS

I. Sampling

Based on Taiwanese Dietary Habit and Food Balance Sheet⁽¹⁴⁻¹⁵⁾, 96 seafood samples (25 species) were purchased at a wholesale market from July to October, 2004. These seafood species are commonly consumed in Taiwan. They were classified into three groups: freshwater fish (2 species), marine fish (11 species) and shellfish and cephalopods (12 species) (Table 1). At least 3 samples were collected for each seafood species.

II. Mercury Analysis

Total mercury concentrations in food were determined by furnace-gold amalgamation using NIC MA2 Mercury Analyzer. About 50 mg fresh sample was weighted into the sample boat and preheated for 4 min at 350°C. The samples was further heated for 4 min at 850°C to vaporize mercury, which was collected in a gold amalgamation tube. The tube was then heated to release mercury into the atomic absorption spectrophotometer⁽¹⁶⁾. Each sample was analyzed in duplicate. Mercury concentrations were reported on mg/kg flesh weight basis.

III. Quality Control

Quality control for each analytical batch consisted of two standard reference materials (DORM-2 dogfish, IAEA

* Author for correspondence. Tel: +886-7- 5252000 ext. 5028;
Fax: +886-7-5255020; E-mail : mhchen@mail.nsysu.edu.tw

Table 1. Details of seafood samples analyzed in this study

Code	Common name	Scientific name	Properties ^a	Sample No.
Fishes				
F1	Tilapia	<i>Oreochromis</i> spp.	O, F	6
F2	Silvery pomfret	<i>Pampus argenteus</i>	O, M	3
F3	Japanese butterfish	<i>Pseneopsis anomala</i>	C, M	3
F4	Milkfish	<i>Chanos chanos</i>	H, F	6
F5	Salmon	<i>Salmo salar</i>	C, M	3
F6	Golden threadfin bream	<i>Nemipterus virgatus</i>	C, M	3
F7	Largehead hairtail	<i>Trichiurus lepturus</i>	C, M	3
F8	Halibut	<i>Hippoglossus</i> spp.	C, M	3
F9	Grouper	<i>Epinephelus</i> spp.	C, M	3
F10	Cobia	<i>Rachycentron canadum</i>	C, M	3
F11	Swordfish	<i>Istiophoridae</i> spp.	C, M	3
F12	Barred Spanish mackerel	<i>Scomberomorus commerson</i>	C, M	3
F13	Tuna	<i>Thunnus</i> spp.	C, M	3
Shellfish and Cephalopods				
S1	Corbicula clam	<i>Corbicula fluminea</i>	O	3
S2	Hard clam	<i>Meretrix lusoria</i>	O	3
S3	Oyster	<i>Crassostrea gigas</i>	O	3
S4	Giant tiger prawn	<i>Penaeus monodon</i>	O	3
S5	Spear shrimp	<i>Parapenaeus</i> spp.	O	6
S6	Lologo squid	<i>Loliginidae</i> spp.	C	3
S7	Cuttlefish	<i>Sepiidae</i> spp.	C	3
S8	White shrimp	<i>Litopenaeus vannamei</i>	O	6
S9	Bigfin reef squid	<i>Sepiotenthis lessonniana</i>	C	3
S10	Flower crab	<i>Portunus pelagicus</i>	O	6
S11	Mud crab	<i>Scylla serrata</i>	O	6
S12	Three spot crab	<i>Portunus sanguinolentus</i>	O	6

^aO: Omnivore; C: Carnivore; H: Herbivore; F: Freshwater fish; M: Marine fish.

2976 mussel) and ten reagent blanks. Detection limits were calculated as the 3-fold of the standard deviation of ten blanks. The limit of detection (LOD) for sample was calculated by the LOD divided by the sample weight. In this study, the recovery of DORM-2 and IAEA 2976 were 90% (4.2 ± 0.5 mg/kg dry weight, $n = 7$) and 92% (0.0559 ± 0.0003 mg/kg dry weight, $n = 3$), respectively. LODs for instrument and sample were determined to be 0.14 ng and 0.0028 mg/kg, respectively. One half of the sample LOD was used to estimate the mercury levels of foods below the LOD.

IV. Mercury Intake Estimation

According to Nutrition and Health Survey in Taiwan (NAHSIT 1993-1996)⁽¹³⁾, the mercury intake was calculated by multiplying the mean concentration of each food group by the weight of weekly food consumption of male or female adults in Taiwan. Total mercury intake was the sum

of mercury intakes from each seafood group. It is assumed that all mercury in the seafood is methylmercury.

V. Risk Assessment

Risk of methylmercury intake was based on the PTWI (provisional tolerable weekly intake), 1.6 µg/kg bw/day set by WHO⁽¹⁷⁾. Based on the average Taiwanese male weights 65 kg and female weights 55 kg⁽¹⁸⁾, the PTWI of methylmercury for the male and female were 104 and 88 µg/week respectively. Health threat may exist if the mercury intake is above the PTWI limit.

VI. Statistics Analysis

One-way Analysis of Variance (one-way ANOVA) was performed to test the significance of variation among the seafood⁽¹⁹⁾. The statistical significance level was set at $p < 0.05$ for all tests.

RESULTS AND DISCUSSION

I. Mercury Levels of Commonly Consumed Seafood

Mercury levels of 25 seafood species ranged from 0.002 to 0.198 mg/kg. Mean mercury level of the fishes (0.072 mg/kg) was higher than that of shellfish and cephalopods (0.028 mg/kg). In addition, significant variation of mercury levels exist in different seafood species ($p < 0.05$). The tuna has the highest mercury level (Figure 1).

The mercury levels of fishes that commonly consumed by Taiwanese ranges from 0.008 to 0.198 mg/kg. The mercury levels among fish species differed significantly ($p < 0.05$). The mercury levels of carnivorous fish are higher than that of herbivorous and omnivorous fish. Even more, the mercury levels of large predatory fish such as halibut, grouper, cobia, swordfish, barred Spanish mackerel and tuna were above 0.090 mg/kg. Those can be explained by the trophic level and the characters of bioaccumulation and biomagnification of mercury in the food chain^(2,4). As compared with the other countries, the mercury levels of salmon is only 1/4-1/6^(8,20) of Italy. The mercury level of tuna is below Italy and Spain⁽²⁰⁻²¹⁾ and is only 1/2-1/5 of UK and Japan^(8,22). The mercury level of swordfish is about 1/5-1/16 of Italy and Japan^(8,20). The mercury level of halibut is slightly higher than Italy⁽²⁰⁾, but is only 1/3 of UK⁽²²⁾. These indicate that the mercury levels of large predatory fish, such as tuna and swordfish, in Taiwan are lower than other countries. The differences might be caused by different sample sizes, ages and the characteristics of captured environment⁽²³⁻²⁴⁾. As to the mean mercury levels of fishes from other countries, Taiwan (0.072 mg/kg) is similar to Canada (0.067 mg/kg)⁽²⁵⁾, but is lower than Spain (0.046-0.549 mg/kg)⁽²¹⁾ and Japan (0.148 mg/kg)⁽⁸⁾. It should be noticed that the mean mercury level was affected by the fish species selected in the studies. For example, the mean mercury level will be higher if fishes with higher mercury level such as tuna, swordfish and sharks were selected⁽²⁵⁾.

The mercury levels of shellfishes and cephalopods, ranging from 0.002 to 0.061 mg/kg, also show significant differences among species. The mercury levels of crabs were higher than other shellfishes and cephalopods (Figure 1). As compared with the mercury levels of similar species reported in the literatures, the mercury level of the shrimp is lower than UK and is about 1/10 of Italy and Japan^(8,20,22). As to octopus, the mercury level is about 1/3-1/7 of Spain, Italy and Japan^(8,20-21). Range of the mercury level of shellfishes and cephalopods in Taiwan was closed to Canada (0.024-0.051 mg/kg)⁽²⁵⁾ but lower than Spain (0.023-0.148 mg/kg)⁽²¹⁾ and Japan (0.050-0.152 mg/kg)⁽⁸⁾.

In conclusion, the mean mercury level of fishes is significantly higher than shellfishes and cephalopods. The finding agrees with the previous studies^(20,26). In addition, the marine fishes that Taiwanese commonly consumed had higher mean mercury levels than freshwater fishes and

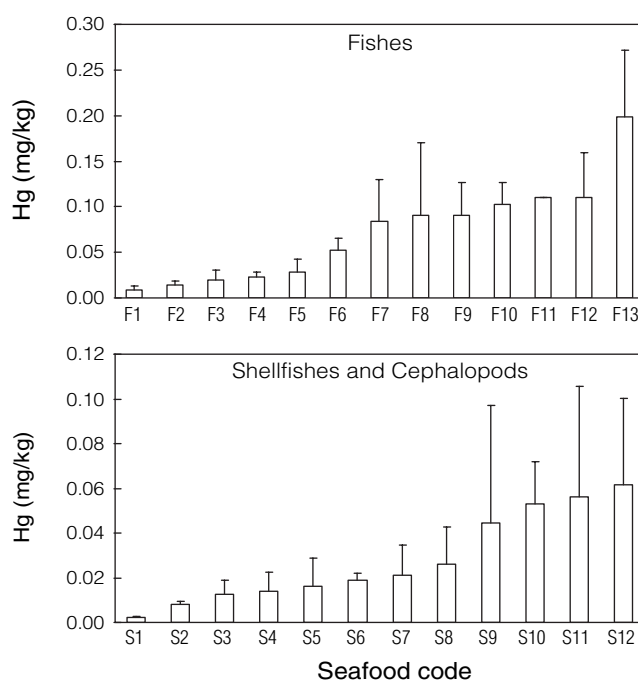


Figure 1. Mercury level of seafood commonly consumed in Taiwan.

shellfishes and cephalopods. It was resulted from the fact that more fish species in high trophic level with higher mercury level were used in the study.

All the mercury levels of seafood commonly consumed by Taiwan residents were far below the guideline levels, 0.5 mg/kg, set by TWDOH (Taiwan Department of Health), EC (European Commission), and FAO/WHO^(4,27-28). To be precise, the mercury levels of small-to-medium size fish, shellfishes and cephalopods were all less than 0.08 mg/kg and that of large predatory fish is lower than 0.2 mg/kg.

II. Methylmercury Intake from Seafood

Over 85% of mercury in marine organisms exists in methylmercury form⁽²⁾. In the study, the estimation of mercury intake was based on the conservative assumption that all the mercury in the fishes was methylmercury. It is shown that the methylmercury intake from seafood for Taiwanese (21-30 $\mu\text{g}/\text{week}$) was below PTWI standard (88-104 $\mu\text{g}/\text{week}$, body weight 55-60 kg) and accounted for only 24-29% of PTWI (Table 2). The methylmercury intake from seafood consumption for male is 1.4 times higher than female, reflected to the fact the amount of seafood consumed by the male is 1.3 times more than female.

As to the contribution of mercury intake from seafood to general public, the fish account for 74-83%. Among them, the marine fish contributes more, accounting for at least 60%. That was due to that Taiwan residents consumed marine fishes followed by freshwater fishes and shellfishes (Table 2). In addition, the mean mercury level

Table 2. Methylmercury intake from seafood of Taiwan population

Food Item	Methylmercury intake				Seafood intake ^a			
	Male		Female		Male		Female	
	µg/week	% Intake	µg/week	% Intake	g/week	% Intake	g/week	% Intake
Freshwater fish	4.1	13.4	2.7	12.9	203	31.7	135	28.0
Marine fish	21.0	69.2	12.9	61.5	241	37.8	148	30.6
Shellfish	5.3	17.4	5.4	25.6	197	30.7	200	41.4
Total	30.4	100	21.0	100	641	100	483	100
PTWI ^b	104	29.2	88	23.8				

^aCalculated from reference 13.

^bPTWI for methylmercury =1.6 µg/kg/week, male and female adults body weight is based on 65 kg and 55 kg, respectively.

of marine fishes was higher than other seafood. Compared with the other countries, mercury intake for Taiwanese is half of Spanish⁽²⁹⁾ and 1/5 of Japanese⁽⁸⁾ (Figure 2), due to the fact that the mean mercury level of the fishes consumed in Spain and Japan were higher than that in Taiwan^(8,29). Furthermore, the fish consumption amount of Spanish was slightly higher⁽²⁹⁾ and of Japanese was 2.5 times higher⁽⁸⁾ than Taiwanese (Figure 2). In conclusion, the study suggested that the amount of fish consumption and the mercury levels of fishes are the two main factors that affect the level of the mercury intake for the general public. Therefore, the dietary recommendation regarding the fish consumption should be addressed.

III. Dietary Recommendation

According to the NAHSIT⁽¹³⁾, the weekly consumption of seafood for male and female in Taiwan were 641 g and 483 g, respectively. The weekly methylmercury intake will not exceed the PTWI standard if the seafood with methylmercury level below 0.18 mg/kg is consumed (Table 3). Based on the assumption that animalistic protein is solely from the seafood and people consumes 30 g of animalistic protein per meal suggested by the TWDOH⁽³⁰⁾, the weekly methylmercury intake will not exceed PTWI standard if the methylmercury level of seafood is below 0.17 mg/kg. If the seafood consumed is only from the predatory fish such as swordfish, barred Spanish mackerel or tuna that have higher mercury level, people should not take more than 300 g (ten exchanges) per week. However, previous studies suggested that the mercury level of large-size predatory fish is positively related to the length of the fish. In addition, it is easy to accumulate mercury up to the level higher than 1 mg/kg for swordfish or tuna longer than one meter^(23,31). Due to the sashimi made from large-size swordfish or tuna is very popular in Taiwan, it is recommended that no more than 3 pieces of the sashimi be taken weekly assuming 15 g per pieces.

CONCLUSIONS

In general, the risk of excessive mercury intake is minimal based on the seafood consumption pattern in Taiwan. However, fishermen, fishmongers, their families, or seafood-lovers who consume more seafood have higher risk of mercury intake. To those people, consumption of seafood with low mercury level or the reduction of seafood consumption is recommended. Since fish is the main sources of mercury exposure for Taiwanese, total diet study for the population that consumes more seafood can be performed in the future and served as the reference for the government to draw up diet recommendations or risk management.

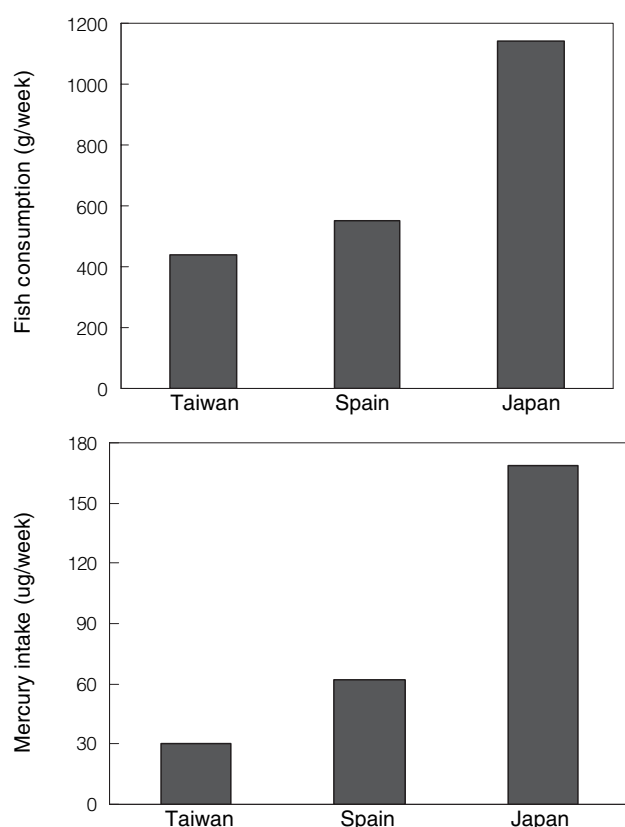


Figure 2. Comparisons of the mercury intake from seafood and fish consumption in different countries.

Table 3. Recommended consumption of seafood for Taiwan population

Methyl mercury (mg/kg)	Seafood	Max. exchange/week ^b (portion/week)	
		Male	Female
< 0.01	Tilapia, Hard clam, Corbicula clam	346.7	293.3
> 0.01-0.05	Milkfish, Salmon, Silvery pomfret, Japanese butterfish, Oyster, Giant tiger prawn, Spear shrimp, Loligo squid, Cuttlefish, White shrimp, Bigfin reef squid	69.3	58.7
> 0.05-0.18	Golden threadfin bream, Largehead hairtail, Halibut, Grouper, Cobia, Small size swordfish, Barred Spanish mackerel, Flower crab, Mud crab, Three spot crab	19.0	16.3
> 0.18-0.5	Tuna	6.9	5.8
> 0.5-1.0	Shark ^d	3.5	2.9
> 1.0-2.0	Large size swordfish and Tuna ^e	1.7	1.5
PTWI ^c		104	88

^aBased on the conservative assumption that all the mercury in seafood was methylmercury.

^bPer exchange means a portion of food as 30g according to the nutrition recommendation of TWDOH.

^cPTWI for methylmercury = 1.6 µg/kg/week, male and female adults body weight is 65 kg and 55 kg, respectively.

^dReference 32.

^eReference 23 and 31.

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