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Natural Detoxifying of Mercury Residues in Mantis Shrimp Using Curcumin

Samaa Mahmoud Elghayati[1], Nada Ibrahim Hussein[2], Hosny Abdellatief Abdelrahman[2*]

[1]Department of Food Hygiene, Faculty of Veterinary Medicine, Alariesh University, Alariesh, Egypt
[2]Department of Hygiene, Safety and Technology of Food, Faculty of Veterinary Medicine, Suez Canal University, Ismailia, Egypt

[*]Corresponding Author: hrahman69@yahoo.com

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ABSTRACT

Mantis shrimp (*Squilla mantis*) is a popular and affordable seafood in the coastal regions of the Mediterranean Sea. It is commonly consumed due to its accessibility and nutritional value, particularly its richness in omega-3 fatty acids. As a predatory crustacean of commercial importance, *S. mantis* also serves as a potential biomarker for marine pollution since it can bioaccumulate heavy metals such as mercury. Mercury contamination in marine ecosystems poses serious risks to human health through seafood consumption, and the accumulation of mercury in *S. mantis* has become an emerging concern in environmental toxicology and food safety. In control mantis shrimp samples, the estimated daily intake (EDI) of mercury was 0.159, lower than the recommended reference dose (RfD). Correspondingly, the health risk (HR) and target hazard quotient (THQ) values were 0.318 and 0.13, respectively, suggesting negligible immediate risk to human consumers. However, prolonged exposure to mercury, even at low concentrations, can still result in adverse health effects. Curcumin, the active compound in *Curcuma longa*, is known for its strong metal-chelating properties. This study investigated the effect of curcumin extract on mercury residues in *S. mantis* under controlled conditions. A total of 24 samples were collected from fish markets in Port-Said City, Egypt, and divided into four groups: control, 0.5% curcumin-treated, 0.5% curcumin with boiling, and 2% curcumin-treated. Results showed a significant reduction in mercury levels, with the 0.5% curcumin plus boiling treatment achieving complete elimination of mercury residues.

INTRODUCTION

Seafood is widely recognized as a valuable component of a healthy diet, offering high-quality protein and essential nutrients with relatively low fat and calorie content. It serves as a good source of important minerals such as calcium, phosphorus, magnesium, and iron, which contribute to metabolic energy production and overall health **(Ravichandran *et al*., 2009)**.

Among marine crustaceans, the mantis shrimp (*Squilla mantis*) is a unique species known for its striking predatory behavior and ecological importance. They inhabit benthic environments, typically residing in burrows and cavities in shallow marine waters

(Hatta, 2016). Commonly referred to as the "prawn killer," mantis shrimp utilize their highly specialized raptorial appendages to deliver powerful strikes to prey, which include fish, mollusks, squids, and other crustaceans. In some cases, they also exhibit cannibalistic tendencies **(Ariyama *et al*., 2021; Jayalakshmi & Parivallal, 2021)**. Due to their high trophic level and predatory feeding habits, *Squilla mantis* is particularly vulnerable to bioaccumulation of environmental contaminants such as heavy metals, making it a suitable bioindicator species for monitoring marine pollution. Among these pollutants, mercury (Hg) is especially concerning due to its persistence, toxicity, and ability to bioaccumulate and biomagnify through aquatic food chains **(Clarkson, 1997; Amlund *et al*., 2007; Hatta, 2016)**.

Mercury exists in various forms, including elemental, inorganic, and organic (primarily methylmercury), which is the most toxic and commonly encountered form in seafood. It acts as a potent neurotoxin, adversely affecting the visual cortex and cerebellum in adults, and causing developmental delays and cognitive impairment in children **(Grandjean *et al*., 1997; Clarkson & Magos, 2006; Mergler *et al*., 2007)**. The presence of methylmercury in seafood poses significant public health risks, especially in populations with high seafood consumption rates. **IARC (2019)** stated that methylmercury compounds were evaluated and classified as Group 2B, possibly carcinogenic to humans. Mercury concentrations in muscle tissue ranged from 0.05 to 0.23mg/ kg wet weight **(Storelli & Marcotrigiano, 2001; Chou *et al*., 2003)**. In another study, **Squadrone *et al*. (2013)** found that mantis shrimp from the Mediterranean area contained mercury concentrations up to 0.15mg/ kg. These values were generally below the permissible limits set by the European Commission (0.5mg/ kg) for mercury in seafood **(Commission Regulation, 2023)**.

Shrimp is generally considered one of the best seafood options; however, a study from the United States Environmental Protection Agency (EPA) and the Food and Drug Administration (FDA) indicates that some people still have concerns about chronic exposure and the cumulative risk of mercury in shrimp **(USEPA, 2024)**. Shellfish are considered good indicators of environmental pollution with heavy metals, which have increased due to rising human activities. They can accumulate high levels of heavy metals due to their position in the food chain, allowing for biomagnification of mercury. The presence of methylmercury in seafood poses a significant public health concern, particularly in populations with high fish consumption. Methylmercury is known for its potent neurotoxic effects, with developing nervous systems being especially vulnerable.

Chronic or excessive exposure through dietary intake has been associated with both neurological and renal impairments, notably in young children and women of childbearing age, who may transmit the toxic effects to the fetus during pregnancy **(CDC, 2004)**. In addition, mercury can promote the oxidative destruction of cell membranes as well as inactivate cellular antioxidants **(WHO, 1990; Houston, 2011)**. The ability of shellfish to accumulate and concentrate mercury in their tissues, along with their position in the food chain, makes them a valuable tool for monitoring environmental pollution **(Marwa *et al*., 2023; El-Sharkawy *et al*., 2025)**.

Curcumin, the active component of turmeric, is being investigated for its potential to mitigate heavy metal toxicity **(Abdel-Hack *et al*., 2021)**. Various studies suggest that curcumin can protect against metal-induced oxidative damage and lipid peroxidation. Curcumin has demonstrated antioxidant, anti-inflammatory, and metal-chelating properties that may reduce mercury-induced tissue damage and decrease metal accumulation in biological tissues **(Agarwal *et al*., 2007; Agarwal *et al*., 2010; Li *et al*., 2011; El-Bahr & Abdelghany, 2015)**.

Industrial wastes are considered one of the primary sources of water pollution. There are about 1,250 industrial plants located in Alexandria (about 60% of them are responsible for marine pollution of the Mediterranean coast of Alexandria) that discharge their wastewater into Lake Marriott. Additionally, about 90% of the rural population lacks access to proper sewer systems or centralized wastewater treatment facilities. As a result, most rural communities rely on on-site wastewater disposal methods, such as septic tanks and direct discharge into local water bodies. These practices pose significant risks to public health, not only through direct human exposure to contaminated water but also indirectly through the consumption of aquatic organisms that inhabit polluted waterways **(Abdel-Shafy & Aly, 2002)**.

MATERIALS AND METHODS

1. Sample collection

A total of 24 random fresh samples of mantis shrimp, *Squilla mantis* **(de Haan, 1844)** were collected from local fishermen at fish markets in Port-Said Governorate, Egypt, during the period from August to October 2024. The samples were immediately transported on ice in sterile insulated containers to the Central Laboratory, Faculty of Veterinary Medicine, Suez Canal University. Upon arrival, the samples were processed under hygienic conditions and randomly divided into four experimental groups (n = 6 per group). All glass ware and equipment used in the study were acid-washed using 5% (w/v) nitric acid in deionized water to eliminate potential contamination from residual metals. The acid-washing was followed by thorough rinsing with deionized water to remove any acid residues.

2. Sample preparation

Shrimp samples were stored at −20°C, as described by **Hamdi (2011)** then shrimp were manually peeled to separate the edible muscle from the exoskeleton. Approximately 2 grams of muscle tissue from each individual sample were weighed and placed in labeled sterile polyethylene bags. The samples were then stored at−18°C until analysis. Prior to analysis, all samples were transported under frozen conditions to the Central Laboratory at Zagazig University for mercury residue determination.

3. Preparation of aqueous curcumin extract

Aqueous solutions of curcumin were prepared using organic turmeric (*Curcuma longa*) powder. 0.5 grams of turmeric powder were added to 100mL of deionized water in a sterile glass container to prepare 0.5% solution. 2.0 grams of turmeric powder were used with the same volume of water for 2% solution. Each mixture was homogenized using an electric mixer for 10 minutes to ensure proper dispersion of the curcumin particles. The mixtures were then left at room temperature (~25°C) for 24 hours to allow maximum extraction of the active compounds. After the extraction period, the solutions were filtered through multiple layers of sterile medical gauze to remove any residual solids. The resulting clear filtrates were stored in clean, airtight glass bottles at 4°C until use **(Chakravarty, 1976; Srinivasan & Shankar, 2023)**.

4. Experimental design

The samples were divided into four groups as follows:

Group 1 (Control group): Untreated samples. Mantis shrimp were placed in glass beakers without any treatment or additives.

Group 2 (0.5% Curcumin + Heat treatment): mantis shrimp were soaked in 200ml of 0.5% curcumin solution for 1 hour and were then boiled for 2 minutes.

Group 3 (0.5% Curcumin): mantis shrimp were soaked in 200ml 0.5% curcumin solution for 2 hours at 25ºC.

Group 4 (2.0% Curcumin): mantis shrimp were soaked in 200ml 2.0% curcumin solution for 2 hours at 25ºC.

Hg analysis

One gram from each of sample was macerated in 5mL of acid digestion mixture (3mL nitric acid 65% (Merck, Darmstadt, Germany): 2Ml Perchloric acid (HCLO4) 70 % **(Uddin *et al.*, 2016)**. The content was left to stand overnight in falcon tubes which incubated at 70ºC for 3 hours in water bath with swirling at 30min. intervals during the heating period. The tubes were allowed to cool, then diluted with 20ml of deionized water and filtered through Whatman No. 42 filter paper. The obtained filtrate was stored at 25ºC until analyzed. For the analytical procedures, mercury residues were determined using vapor atomic absorption spectroscopy (Shelton, CT, USA).

Quality assurance and quality control

The reference material DORM-3 (fish protein, National Research Council, Canada) was used to ensure the accuracy and validity of the heavy metal analyses. Recovery rates ranged from 80 to 115%, and the detection limit for mercury was 0.2μg/ g wet weight (ppm).

Estimated daily intake (EDI)

Estimated daily intake was calculated according to **FAO (2003)**.

Health risk (HR)

The non-cancer risk of Hg for shellfish consumers in Egypt was evaluated **(USEPA, 1989)**. For non-carcinogenic effects, the estimated daily intake (EDI) was compared to the standard reference dose (RfD) stated by **USEPA (2010)**.

Hazard index (HI)

The hazard index was calculated to determine the risk of exposure to mixed contaminants according to **USEPA (1989)**. An HI or hazard ratio (HR) greater than 1 indicates a potential human health risk, whereas a value less than 1 suggests no adverse health effects.

Target hazard quotient (THQ)

The THQ provides an estimate of the non-carcinogenic risk level from exposure to heavy metals and was calculated according to the standard assumptions of the EPA Region III Risk-Based Concentration Table **(USEPA, 2000)**. A THQ value less than or equals to 1 indicates a low likelihood of risk, suggesting the exposed population will not face long-term adverse effects. In contrast, a THQ greater than 1 suggests a potential health risk.

Carcinogenic slope factor (CSF)

The CSF expresses the risk per mg/kg-day of intake from a heavy metal and is used to estimate the lifetime cancer risk associated with exposure to a carcinogen **(USEPA, 1989; USEPA, 2005)**. However, CSF values for mercury (Hg) have not yet been published by the USEPA.

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Statistical analysis

Data were analyzed using IBM SPSS Statistics (Version 27.0; IBM Corp., Armonk, NY). One-way ANOVA was performed to identify significant variations between treatments. For non-normally distributed data (Hg) and reduction percentages, the Kruskal–Wallis H test was applied.

Correlation analysis

The correlation coefficient was calculated to examine the relationships between the different interventions applied.

Log reduction

Log reduction was calculated according to the following formula:

$$\text{Log reduction} = \log 10\ (A/B)$$

Where, A is the control and B is the treatment

The percentage reduction was calculated as:

$$\text{Reduction}\ \% = [(Co - Cf)/\ Co] \times 100$$

Where, Co and Cf are the initial and equilibrium concentration (mg/kg/ww) of metal ions **(USEPA, 1996)**.

RESULTS

Table 1. Effect of curcumin on mercury concentrations in the mantis shrimp (Kruskal-Wallis H test descriptive as non normally distributed data

Treatment	Control	0.5% Curcumin	2% Curcumin	0.5% Curcumin+ Boiling	Kruskal-Wallis H	*DF	**Asymp. Sig	***MPL
Mean rank	14.5	8.0	7.5	4.0	11.058	3.0	0.011	**≤0.50**
EDI	0.159	0.020	0.032	0.0				
HR	0.318	0.040	0.064	0.0				
THQ	0.13	0.017	0.027	0.0				

***DF ;** Degree of freedom

****Asymp. Sig.**; Asymptotic Significance

*****MPL**: Maximum Permissible Limits **(mg/kg)**

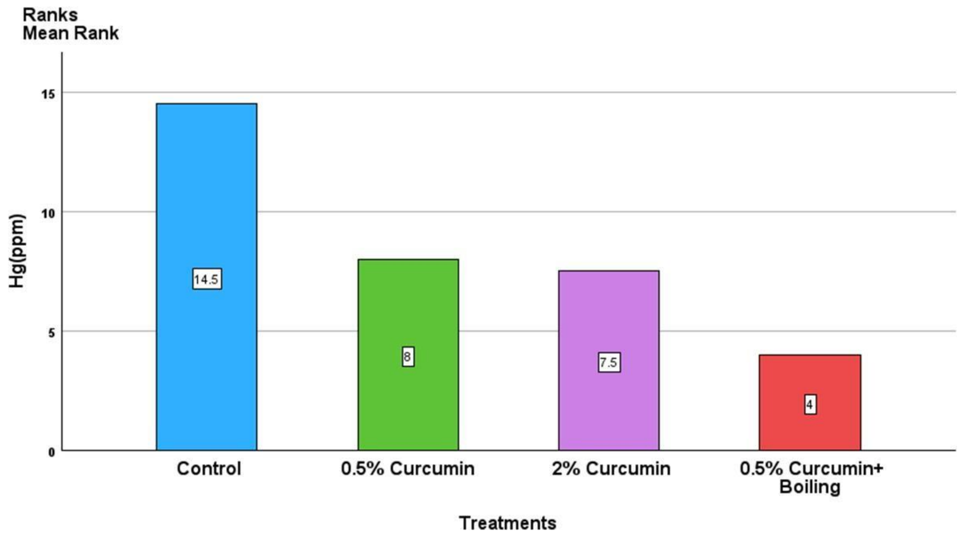

Fig. 1. Mean rank (Kruskal-Wallis) of Mercury concentration in mantis shrimp tissue in different treatments

Table 2. Spearman correlation coefficient between measured mercury in shrimp samples and the effect of different treatments

Correlations					
		Hg (ppm)	**Boiling**	**Curcumin 0.5%**	**Curcumin 2%**
Spearman'srho	Hg (ppm) Boiling	1.000	-.515**	-.153	-.139
	Curcumin 0.5%	-.515**	1.000	0.041	-.194
	Curcumin 2%	-.153	0.041	1.000	-.191
		-.139	-.194	-.191	1.000

**.Correlation is significant at the 0.01 level (2-tailed).

Table 3. Reduction efficiency%

	0.5% Curcumin	2% Curcumin	0.5% Curcumin with boiling
Hg (ppm)	86.96	79.71	100.00

DISCUSSION

The results presented in Table (1) revealed a significant difference between the mean ranks of the different treatments (P = 0.011; Kruskal–Wallis H = 11.058, df = 3). The mean ranks for the control group, 0.5% curcumin-treated group, 0.5% curcumin with boiling group, and 2% curcumin-treated group were 14.5, 8.0, 4.0, and 7.5, respectively. These results are higher than those reported by **Candra *et al*. (2019)** and **Gomboa-Garcia *et al*. (2020)**. Such variation may be attributed to higher water pollution in the areas where the samples were collected, as the marine environment has a strong influence on the metal content of mantis shrimp.

All control and treated samples fell within the maximum permissible limit (MPL) reported by **ES (2010)**, which states that mercury should not exceed 0.50mg/ kg. The mean value of mercury in the control samples was 0.23 ± 0.019mg/ kg.

Oxidative damage caused by harmful metals in aquatic species can be mitigated by exogenous antioxidants **(Sant'Ana & Mancini-Filho, 2000)**. Curcumin, a natural antioxidant, possesses metal-chelating properties, forming stable complexes with toxic metals that facilitate excretion from tissues. It also exerts protective effects against toxic metals through its antioxidant activity **(Bakar & Lajis, 2018; Giri *et al*., 2021)**. This finding is consistent with the results illustrated in Table (2), where a negative correlation is observed between curcumin treatment and mercury levels: r = –0.153 for 0.5% curcumin and r = –0.139 for 2% curcumin. Conversely, a non-significant positive correlation (r = 0.041) is found between boiling and 0.5% curcumin treatment. This may be explained by the fact that boiling supports the effect of curcumin by denaturing Hg-bound proteins, thereby enhancing mercury removal.

Regarding the removal efficiency of the different treatments (Tables 2, 3), the 0.5% curcumin with boiling treatment achieved the highest efficiency (100%). This was further supported by the strong significant negative correlation between boiling and Hg (r= –0.515, P= 0.01). In contrast, the 2% curcumin treatment exhibited a lower removal efficiency (79.71%) compared to the 0.5% curcumin treatment (86.96%). This suggests that increasing concentration does not always correspond with higher removal efficiency. In some cases, increasing the concentration of the treatment substance may actually decrease efficiency, as removal methods such as adsorption or coagulation have a limited capacity. Once this capacity is reached, further addition does not enhance removal **(Clark, 2025)**.

As shown in Table (1), the estimated daily intake (EDI) of mercury in control mantis shrimp samples was 0.159, which is below the recommended reference dose (RfD). Consequently, the hazard ratio (HR) and target hazard quotient (THQ) for the control group were 0.318 and 0.13, respectively, indicating negligible human health risk from mantis shrimp consumption. However, prolonged exposure to mercury, even at low concentrations, can cause serious health issues, including neurological damage, kidney failure, respiratory problems, and increased cancer risk due to its cumulative effect over time **(USEPA, 2024)**. These findings underscore the importance of continuous monitoring of mercury levels in seafood and the implementation of public health advisories to minimize exposure in vulnerable populations **(CDC, 2004)**.

CONCLUSION

The obtained results demonstrated that mantis shrimp contained mercury levels that did not exceed the recommended permissible limits set by Egyptian and international standards. However, mercury residues in mantis shrimp cannot be easily removed from tissues by simple washing with water. In its most toxic form, mercury accumulates within the tissues and muscles of shrimp through the food chain. Mercury in either elemental or inorganic forms has not yet been classified as a carcinogen by major regulatory agencies; therefore, no cancer slope factor (CSF) is currently assigned. Risk assessment for mercury exposure instead relies on the reference dose (RfD) and target organ toxicity. Nevertheless, prolonged exposure to mercury, even at low concentrations, can lead to serious human health problems. Importantly, the present study found that treatment with 0.5% aqueous curcumin extract combined with boiling for 2 minutes completely eliminated mercury residues from mantis shrimp samples.

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Declaration of Conflict of Interest

The authors declare that there is no conflict of interest.

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إزالة سموم الزئبق طبيعيًا من روبيان السرعوف باستخدام الكركمين

سماء محمود الغاياتي[1] ندي ابراهيم حسين[2] حسني عبد اللطيف عبد الرحمن[2]

[1]قسم الرقابة الصحية علي الاغذيةالغذاء - كليه الطب البيطري - جامعه العريش

[2]قسم صحة وسلامة وتكنولوجيا الغذاء- كليه الطب البيطري - جامعه قناه السويس

تشتهر المناطق الساحليه بمأكلوتها البحريه ومن ضمنها الروبيان والمعروف تجاريا باسم الشيكال اوالسرعوف وهو أحد انواع القشريات الذي انتشرت في الاسواق المصريه لسعره الزهيد مقارنة بالجمبري ويميزه ايضا طعمه المقبول والقيمه الغذائيه العاليه لاحتوائه على بعض الأحماض الأمينيه والدهنيه والأوميجا 3. ويعيش الشيكال في المناطق البحرية التي طالها التلوث البيئي نتيجة العمران الجديد والتلوث الصناعي والتعدين ومخلفات السفن وغيرها. ومما لاشك فيه أن الزئبق هو أحد المعادن الثقيلة الموجودة في أكثر من شكل في البيئه. ومع تطور التلوث البيئي أصبح الزبئق موجودا في المسطحات المائيه. ومع الهرم الغذائي والتراكم الحيوي انتقل للكائنات البحريه ومن ضمنهم الشيكال لذا كان واجب علينا تحليل الزئبق في الشيكال لكثرة الاقبال عليه واستهلاكه مع عمل بعض المحاولات لتقليل المخاطر المحتملة على المستهلك من مخاطر الزئبق مثل اختبار المستخلص المائي للكركم كمضاد للأكسده. وعلى ذلك تم تحليل 24 عينة من الشيكال من مصادر جمعت من أسواق الأسماك في بورسعيد وتم تقسيمهم لأربع مجموعات(6 لكل مجموعة). ووجد أن متوسط نسبة بقايا الزئبق في أنسجة السرعوف هي0,019 مللجرام/كجم والتي تشير الى عدم تجاوز نسبة الزئبق 0.50 مللجرام/كجم مما يشير الى أن 100% من العينات مطابقة للمواصفات القياسيه المصريه.ومع استخدام مستخلص مائي للكركم بتركيزات مختلفة وجد أن لها تأثيرا في خفض نسبة متبقيات الزئبق كما وجد أن الغليان لمدة دقيقتين ل 0.50% من مستخلص الكركم المائي قد أدت الى ازالة الزئبق بنسبة 100%. فيجب الحرص أثناء تناول الشيكال بصفة مستمرة وعلى فترات متقاربة لتجنب المحتوي التراكمي للزئبق على المدى الطويل ولتجنب الاثار التراكمية الضارة.