The contents of Cd, Cu, Pb and Zn of the white shrimp *Litopenaeus vannamei* (Boone, 1931) of six coastal lagoons of Sinaloa, NW Mexico

Contenido de Cd, Cu, Pb y Zn en el camarón blanco *Litopenaeus vannamei* (Boone, 1931) de seis lagunas costeras de Sinaloa, NW de México

Martín G. Frías-Espericueta[1], Isidro Osuna-López[1], Domenico Voltolina[2], Marco A. Beltrán-Velarde[1], Gildardo Izaguirre-Fierro[1], Gabriel López-López[1], Maria D. Muy-Rangel[3] and Werner Rubio-Carrasco[3]

[1]*Environmental Studies Laboratory, Faculty of Marine Sciences, Autonomous University of Sinaloa, P.O. Box 1132, Mazatlán 82000, Sinaloa, Mexico*
[2]*UAS-CIBNOR Laboratory, Center of Biological Research of the North West, P.O. Box 1132, Mazatlán Sinaloa, Mexico*
[3]*CIAD, Research Center for Food and Development, Culiacán Unit, P.O. Box 32-A, Culiacán 80129, Sinaloa, Mexico*
voltolin04@cibnor.mx

Resumen.- El camarón *Litopenaeus vannamei* es la especial más importante en la pesquería tradicional de las lagunas costeras del estado de Sinaloa (NW de México), y la mayoría de sus capturas son consumidas localmente. Estas lagunas reciben grandes volúmenes de efluentes agrícolas, industriales y urbanos, por lo cual el consumo del camarón podría representar un riesgo para la salud humana. El contenido medio de Cd, Cu, Pb y Zn en el hepatopáncreas de las capturas comerciales en seis lagunas de Sinaloa fue mayor que su respectivo valor en el músculo; no se observó una correlación entre el contenido de Cd, Cu y Pb de los dos tejidos (P>0,1); en el caso de Zn la correlación resultó significativa con un bajo nivel de probabilidad (P≤0,05). La concentración en el músculo del camarón fue similar o menor que la determinada en capturas comerciales de otros crustáceos en otras regiones. Con base en estos resultados, el consumo de los camarones locales no constituye un riesgo para la salud humana.

Palabras clave: Metales pesados, crustáceos, consumo humano

Abstract.- *Litopenaeus vannamei* is the most important shrimp species in the traditional fishery of the coastal lagoons of the State of Sinaloa (NW Mexico), and most of the landings are consumed locally. Since these lagoons receive important volumes of agricultural, industrial and urban effluents, consumption of this shrimp could pose risks to human health. The mean content of Cd, Cu, Pb and Zn determined in the hepatopancreas of shrimp from commercial landings from six lagoons of Sinaloa were higher than those of the muscle. There was a weak correlation between the Zn content of the two tissues (P≤0.05) and the correlations were not significant for Cd, Cu and Pb (P>0.1). The concentrations found in the shrimp muscle were comparable or lower than those determined in commercial landings of different crustaceans from other geographic areas. According to our results the consumption of local shrimp poses no risks to human health.

Key words: Heavy metals, crustaceans, human consumption

Introduction

The state of Sinaloa (NW Mexico) has > 600,000 ha of agricultural land, mostly dedicated to intensive, highly mechanized cultures that drain into its coastal waters and lagoons (SAGARPA 2007), and these effluents are important sources of several heavy metals. Additional sources of metals are industrial, municipal and aquaculture effluents, which may cause an increase of the metal contents of the sediments (Green-Ruiz & Páez-Osuna 2003, Frías-Espericueta *et al*. 2004) and of aquatic organisms (Páez-Osuna *et al.* 2002, Frías-Espericueta *et al*. 2005).

In this study we evaluated the Cd, Cu, Pb and Zn contents in the hepatopancreas and muscle of the white shrimp *Litopenaeus vannamei* (Boone, 1931) which, in view of its commercial value and of the volumes landed, is the most important species caught by traditional fishery in several lagoonal systems of Sinaloa. For these reasons, we felt that it was important to evaluate possible health risks for consumers.

Materials and methods

Sampling sites

The most important lagoons among the > 40 coastal water systems of the State of Sinaloa are Navachiste (NAV), Santa María-La Reforma (SMR), Altata-Ensenada del Pabellón (AEP), Urías, Huizache-Caimanero (HUC) and Teacapán-Agua Grande (TAG) (Fig. 1). For this reason, these lagoons were chosen for this study.

All receive the same types of anthropogenic discharges, mainly effluents from agricultural areas and from rural communities, and all support the same human activities (traditional fisheries and semi-intensive shrimp culture). In addition, AEP and Urías lagoons receive the municipal and industrial wastewaters of the cities of Culiacán and Navolato (≈950,000 inhabitants) and of Mazatlán (≈400,000 inhabitants), respectively.

Sampling and analytical procedures

Three samples of 30 shrimp of between 9.5 and 12 cm total length (total: 90 shrimp/lagoon) were obtained from local fishermen operating in different areas of each lagoon between September and October 2006, which is the peak of the shrimping season in bays and lagoons of the Mexican NW. This, depending on the results of the official estimates of the National Fisherie Institute, usually lasts from August to November of each year.

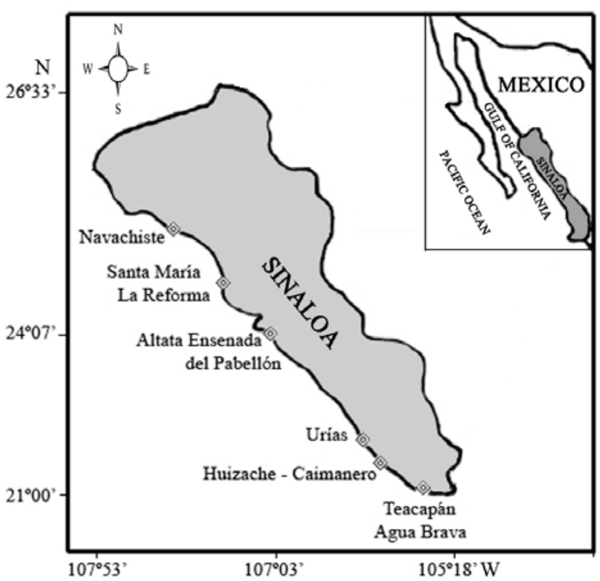

Figure 1

Location of the six coastal lagoons in Sinaloa, Mexico

Localización de las seis lagunas costeras en Sinaloa, México

In the laboratory, the organisms were dissected and the abdominal muscles (edible) and hepatopancreas (because small shrimps are dried and marketed whole or as shrimp meal, used locally as flavouring agent) were separated, freeze-dried (mean water content: muscle=76%, whole shrimp=80%), ground and homogenized in a Teflon mortar, giving three composite samples of each tissue for each lagoon. These were analyzed in triplicate, following the multiple standard addition method (Miller & Miller 1988). After digestion in concentrated nitric acid (metal analysis-grade), the samples were evaporated to dryness (90°C), dissolved again in 2 M nitric acid, centrifuged and the supernatant was analyzed by flame atomic absorption spectrophotometry (Frías-Espericueta *et al*. 2005). The detection limit for these metals was 0.01 µg g^{-1}.

In order to check the purity of reagents and for possible contamination for each run, one blank was included using the same procedure used for samples (Drava *et al*. 2004). All material and glassware used in sampling and sample handling were acid-washed as in Moody & Lindstrom (1977).

The accuracy and precision of the method was evaluated using shrimp tissue MA-A-3/TM (IAEA 1987) as reference material, with recovery percentages of 82.4%, 89.8%, 85.6% and 96.3% for Cd, Cu, Pb and Zn, respectively. The mean contents (µg g^{-1}, dry weight) of the three composite samples of each lagoon were compared by one-way analysis of variance (ANOVA) or Kruskall-Wallis tests, separating the different means or mean ranks with the corresponding Tukey's or Dunn's tests. The content of each metal determined in each sample of muscle (n=18) was related to that of the corresponding hepatopancreas sample using Pearson's linear correlation analysis. The probability level used in all tests was α = 0.05 (Zar 1996).

Results and discussion

The generally low values of the standard deviations and of the corresponding coefficients of variation show that the three samples of each system had similar metal concentrations (CV<20%). Apart from HUC (3%), the exceptions for the hepatopancreas were CV between 23 and 33% for Cd, and Pb between 41 and 45% in AEP and Urías. In TAG, the CV values for muscle were 35 and 29.5% for Cd and Cu.

The mean contents of all metals were lower in the muscle than in the corresponding hepatopancreas samples (Table 1), which is in agreement with most literature on the metal contents in the tissues of different aquatic organism, because the hepatopancreas is the main organ for metal accumulation (Roesijadi & Robinson 1994, Yang *et al*. 2007).

Table 1

Means and standard deviations of the heavy metal contents (µg g^{-1}, dry weight) in the muscle (A) and hepatopancreas (B) of *L. vannamei* of the lagoons. Different letters indicate significant statistical difference (one-way ANOVA, α = 0.05); a≤ab≤b and a<b

Valores medios y desviaciones estándares del contenido de metales (µg g^{-1}, peso seco) en el músculo (A) y hepatopáncreas (B) de *L. vannamei* de las lagunas. Letras diferentes indican diferencia estadística significativa (una vía ANOVA, α = 0,05); a≤ab≤b and a<b

	Lagoon	Cd	Cu	Pb	Zn
A	NAV	0.40±0.04a	19.04±2.14ab	5.62±0.19ab	45.64±7.95a
	SMR	0.44±0.07ab	14.86±1.14a	5.18±0.69ab	54.59±2.37ab
	AEP	0.36±0.02a	19.09±1.62ab	4.89±0.41a	55.50±2.66ab
	Urías	0.40±0.06a	21.85±3.26b	5.52±0.49ab	53.84±5.65ab
	HUC	0.39±0.04a	15.89±1.23ab	4.21±0.57a	60.55±5.38b
	TAG	0.76±0.27b	13.33±3.93a	6.93±1.38b	64.18±2.92b
B	NAV	4.39±1.47ab	151.39±5.11ab*	18.84±2.80b	120.89±18.10b
	SMR	5.90±1.36b	287.43±136.7ab*	9.41±1.72a	152.05±11.35c
	AEP	7.97±2.65b	384.57±34.96b*	9.31±4.20a	129.67±4.64c
	Urías	1.10±0.30a	89.71±16.11ab*	13.37±5.46ab	92.64±9.98b
	HUC	3.03±0.11a	49.44±5.98a*	5.45±0.69a	61.45±9.52a
	TAG	1.58±0.56a	87.01±32.89ab*	9.76±0.80a	92.16±8.31b

*nonparametric test

There were no significant correlations between the metal contents of the two tissues (Cd: r = -0.275; Cu: r = 0.197; Pb: r = 0.372; n=18; P>0.1 in all cases) with the exception of Zn (r = -0.447, P≤0.05). This is probably explained by the difference in the distribution of metals in both tissues: the highest Cd, Pb and Zn contents of the muscle were in the most southern lagoon (TAG). This distribution did not coincide with that of the hepatopancreas samples, which in general showed higher values in the northern lagoons (Cd and Cu in AEP; Pb in NAV and Zn in SMR: Table 1).

This lack of correlation between tissues may be related to different stages of the kinetic mechanisms associated to metal uptake, transport, storage and release, which is very complex and reflects the diverse compartments in which metals are stored and from which they are mobilized (Roesijadi & Robinson 1994).

There were no significant correlations between the levels of each metal determined in the three samples of the six lagoons (P>0.05 in all cases), and the concentrations patterns of the four metals were Zn>Cu>Pb>Cd (muscle) and Cu>Zn>Pb>Cd (hepatopancreas). Since crustaceans may regulate their internal concentrations of the essential metals Cu and Zn, the difference between tissues is probably due to their different metabolic requirements (Kargin *et al*. 2001, Pourang & Dennis 2005).

The possible sources of these metals are natural and anthropogenic: a likely source of Pb is sediment enrichment caused by atmospheric transport of previous combustion engine emissions, when tetraethyl Pb was used as antiknock agent in Mexican gasoline; agricultural activities are likely to add important amounts of Cd, Cu and Zn to the natural levels, because fertilizers are important sources of Cd and Cu and Zn based-agrochemicals are widely used in intensive agriculture (Alloway 1990).

However, the alluvial soils of Sinaloa lie in the Mexican Pacific Plain and originate from the mineral-rich Sierra Madre Occidental (Gonzalez-Medrano 2004), where gold, silver and copper (whose ores are frequently associated with Pb, Cd and Zn, among other metals) have been extensively mined since colonial times.

Apart from *Panulirus homarus* (Cd and Pb) and *Callinectes sapidus* (Pb) of the Connecticut estuaries, our values of Cd, Pb and Zn in muscle and hepatopancreas are comparable or lower than those found in other crustaceans of different geographic origin. In particular, with the exception of Zn, the data available for some lagoons of NW Mexico (Frías-Espericueta *et al*. 2005) are close to those of this study (Table 2).

Table 2

Muscle (m) and hepatopancreas (h) mean metal contents (µg g^{-1}, dry weight) in crustaceans from other areas of the world

Contenido medio de metal (µg g^{-1}, peso seco) en el músculo (m) y hepatopáncreas (h) de crustáceos de otras áreas del mundo

Species		Zone	Cd	Cu	Pb	Zn	Reference
Panulirus homarus							
	(m)	Southern Oman	0.03	39.3	0.51	-	(Fowler *et al*. 2007)
	(h)		51.5	51.9	0.18	-	
Callinectes sapidus							
	(m)	Connecticut estuaries	0.93*	66.9*	0.27*	133.3*	(Jop *et al*. 1997)
	(h)		4.39*	240.7*	0.63*	115.6*	
Penaeus semisulcatus							
	(m)	Iskenderun Gulf, Turkey	3.47	32.3	19.2	53.8	(Çoğun *et al*. 2005)
	(h)		25.6	638.7	72.7	290.8	
Metapenaeus monoceros							
	(m)	Iskenderun Gulf, Turkey	0.72	23.9	13.8	64.2	(Kargin *et al*. 2001)
	(h)		3.95	671.7	57.9	271.6	
Litopenaeus vannamei							
	(m)	Lagoons NW Mexico	0.68	13.01	2.35	29.7	(Frías-Espericueta *et al*. 2005)
Litopenaeus vannamei							
	(m)	Sinaloa, NW Mexico	0.44	16.2	5.1	56	This study
	(h)		4.06	158.6	10.9	102.5	

*Calculated from wet weight, assuming 0.24 as a conversion factor (Pourang & Dennis 2005)

Table 3

Maximum daily ingestion of the four metals (µg $person^{-1}$ day^{-1}: FDA 1993, WHO 1998) and suggested individual daily consumption (grams, wet weight) of shrimp muscle of Sinaloa lagoons

Ingestión máxima diaria de los cuatro metales (µg $persona^{-1}$ $día^{-1}$: FDA 1993, WHO 1998) y consumo diario sugerido por persona (en gramos, peso húmedo) de músculo de camarón de las lagunas de Sinaloa

Metal	Maximum ingestion µg $person^{-1}$ day^{-1}	Suggested daily consumption
Cadmium	55	520.8
Copper	>3000	771.6
Lead	750	610.4
Zinc	>45000	3347.0

Cd and Pb are of concern for human health. For this reason, we calculated the maximum allowable daily consumption of Sinaloa shrimp muscle, using as reference values the maximum recommended daily ingestion of the four metals (FDA 1993, WHO 1998). According to these values, Cd is the metal of major concern, since the risk level would be equivalent to a regular daily consumption of 520 g of fresh shrimp muscle (55 µg Cd day^{-1} $person^{-1}$; Table 3), indicating that the consumption of *L. vannamei* caught in the coastal lagoons of Sinaloa poses no risks to human health, although care should be taken in the case of whole shrimp, because Cd content in hepatopancreas is about one order of magnitude higher than those of muscle. Besides, the permissible limits for commercial purposes are 12.5 and 6.25 µg g^{-1} (dry weight) for Cd and Pb, respectively (FDA 2001), which are higher than those reported in the present study (0.44 and 5.1 µg g^{-1} for Cd and Pb in muscle).

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