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Presence of trace elements in fishes from the Chaco-Pampeana plain (Argentina)

Presencia de elementos traza en peces de la llanura Chaco-Pampeana (Argentina)

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Abstract

The Chaco-Pampean plain is one of the greatest plains worldwide; present a wetland macro system (lagoons, marshes, rivers, streams, channels). The water quality of these environments is diverse and has different trace elements natural (As, F, Mo and V) and anthropogenic (Cr, Cu and Pb). The Chaco Pampean plain has an important diversity of fish species however the species of commercial importance are limited. This paper presents the reviews of the studies related to the presence of trace elements in tissues of commercial fishes (shad *Prochilodus lineatus* and silversides *Odontesthes bonariensis*) in the Chaco-Pampean plain in recent decades and a discussion about associated information gaps is presented.

The presence of trace elements in commercial fish muscle is a major problem for food security. The results showed that most of the elements present in shad are in lower levels than the maximum limits set by the Argentine Food Code (CAA, 2014). In the case of Pb present in the muscle of the shad, the determined values exceed those considered by the European Food Safety Authority. In the case of silversides the values of As, Pb, Hg are mostly lower than those maximum recommended by the Argentine Food Code. However, according to the European Food Safety Authority, the lower limit on the benchmark dose for a 10% response (BMDL) values associated with health risk for As.

Keywords: Chaco-Pampean plain, shad, *Prochilodus lineatus*, silversides *Odontesthes bonariensis*, food safety

Resumen

La provincia Chaco-Pampeana es una de las más grandes planicies a nivel mundial, presenta un macrosistema de humedales (lagunas, marismas, ríos, arroyos y canales). La calidad de agua de estos ambientes es diversa y tiene diferentes trazas de elementos de origen natural (As, F, Moand V) y antrópicos (Cr, Cu and Pb). La planicie Chaco Pampeana tiene una importante diversidad de peces, sin embargo las especies comerciales son limitadas. El presente artículo presenta una revisión de los estudios relacionados con la presencia de elementos traza en los tejidos de peces comerciales (sábalo *Prochilodus lineatus* y pejerrey *Odontesthes bonariensis*) en la provincia Chaco-Pampeana en décadas recientes y se realizó una discusión asociada.

La presencia de elementos traza en músculo de peces comerciales es el mayor problema para la seguridad alimentaria. Los resultados muestran que los elementos más importantes presentes en sábalo están por de bajo de los límites máximos permitidos por el código argentino de alimentos (CAA 2014). Sin embargo, , tomando en cuenta el Pb presente en el músculo, se determinaron valores que excedieron los limites considerados por la autoridad europea de seguridad alimentaria (EFSA 2010). En el caso del pejerrey, los valores de As, Pb, y Hg fueron muy bajos en comparación a los recomendados por el código argentino de alimentos. Por otro lado, considerando las dosis de ingesta propuestas por EFSA (2010), existe un riesgo leve para la ingesta de pejerrey de algunos de los cuerpos de agua estudiados.

Palabras clave: Planicie Chaco-Pampeana, sábalo, *Prochilodus lineatus*, pejerrey *Odontesthes bonariensis,* seguridad alimentaria

Introduction

The Chaco-Pampean plain is one of the greatest plains worldwide. The climate is warm with an average temperature of 17 ° C in the north and 13 ° C in the south (Servicio Meteorológico Nacional 1992). The annual rainfall reaches 1000 mm in the northeast and decreases to the south and west to reach values of 400 mm (Iriondo 2004). This situation makes that the precipitation waters drain off in a relative slowly way and therefore a wetland macro system appears between lagoons, marshes, rivers, streams, channels and ravines (Sosnosky & Quirós 2005; Fernández Cirelli et al . 2006). This variety of wetlands has unique characteristics as high complexity, water variability and large geographical extent, working as a nutrients trap because of chemical transformations, concentration and release processes, depending on the existence of the rainfall, the runoff, the contribution of rivers and underground water flow (Iriondo 2004; Volpedo & Fernandez Cirelli 2013; Puntoriero et al. 2014 a,b;. 2015; Schenone et al. 2014.). Lotic systems presents on the plain are relatively few being the Salado River, the main water basin, while lentic systems are numerous. They were counted 525 permanent water bodies and 904 temporary ones

(Toresani et al. 1994). These water bodies have different geomorphological origins and limnological features (Volpedo & Fernandez Cirelli 2013).

The water quality of these environments is diverse and has different trace elements both natural and anthropogenic. Among the natural elements present in the water of the region we found As, F, Mo and V (Rosso et al. 2011; Puntoriero et al. 2014 a, b, c, 2015; Avigliano et al. 2015). These elements have a common origin and come from the weathering of Pampean loess generated in the Andes formation. Other elements such as Cr, Cu and Pb may come from the contribution of the industrial and agricultural activities and domestic effluents (Schenone et al. 2014; Avigliano et al. 2015).

The Chaco Pampean plain has an important diversity of fish species however the species of commercial importance are limited. Among these we can mention the shad (*Prochilodus lineatus*), the silversides (*Odontesthes bonariensis*), the wolf fish (*Hoplias malabaricus*), the leporinus (*Leporinus obtusidens*), the carp (*Cyprinus carpio*), the golden fish (*Salminus brasiliensis*), and some catfish as the surubi (*Pseudoplatystoma* sp.) and the patí (*Luciopimelodus pati*) where most commercially important species for the region are the shad and the silversides (Espinach Ros & Fuentes 2000; Avigliano & Volpedo 2013).

This paper presents the reviews of the studies related to the presence of trace elements in tissues of commercial fishes (shad *P. lineatus* and silversides *O. bonariensis*) in the Chaco-Pampean plain in recent decades and a discussion about associated information gaps is presented.

Trace elements in fish muscle

The shad and the silversides are the first two commercially important species of the Pampean plain. The shad is associated mainly with the great rivers of the Río de la Plata Basin (Paraná and Uruguay Rivers) although for its life cycle it also migrates to inhabit lentic water bodies of the floodplain (Sverlij et al. 1993). In the late 90's the catch of the shad has increased to a peak of 36,000 tons in 2004 and gradually has decreased to 12,148 t in 2012 (MINAGRI 2014) due to the application of restrictive measures (Volpedo 2014).

The silverside is distributed in most water bodies of the Chaco-Pampean plain and there are several groups of populations of this species (Tombari & Volpedo 2008; Avigliano & Volpedo 2013, Avigliano et al. 2013; 2014).

Several authors have determined the concentration of various metals in different organs of these species (Lombardi et al. 2010; Rosso et al. 2013; Puntoriero et al. 2014a, b; Schenone et al. 2014; Avigliano et al. 2015; Vazquez et al. 2015).

The presence of trace elements in commercial fish muscle is a major problem for food security. Recently, several studies on the presence of various trace elements in muscle of *P.*

lineatus shad and *O. bonariensis* silversides from different aquatic environments of Chaco-Pampean plane have begun (Table 1).

The results obtained by these authors showed that most of the elements present in shad are in lower levels than the maximum limits set by the Argentine Food Code (CAA 2014). In the case of Pb present in the muscle of the shad (Schenone et al. 2014), the determined values exceed those considered by the European Food Safety Authority (EFSA 2010). The rest of the determined elements (Li, B, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ga, Se, Rb, Sr, Mo, Ag, Cd, Sn, Sb, Te, Ba, Ti , Bi, U, As, Na, Mg, K and Ca) are below recommended levels.

In the case of silversides the values of As, Pb, Hg (Table 1) are mostly lower than those maximum recommended by the Argentine Food Code (As: 1 mg / kg, Pb: 0.3 mg / kg and Hg: 0.5 mg / kg dry weight). However, according to the European Food Safety Authority (EFSA, 2010), the lower limit on the benchmark dose for a 10% response (BMDL) values associated with health risk for As ranged from 4.9 to 24 µg/kg of body weight (b w) per week.

Fortunately, the level of As in muscle of this species was below the maximum suggested for human consumption by several international authorities such as Hong Kong (2.3 µg/g) Hong Kong Government. Food Adulteration (Metallic Contamination) regulations. Laws of Hong Kong (2, 1987), and New Zealand and Australia (2.01 µg/g; Australia New Zealand Food Authority, 1999). However, the level of As in *Odontesthes bonariensis* of Quequén Salado river determinate for Rosso et al. (2013), was slightly over the limit suggested by United States (1.2 µg/g; USEPA 2000). In a review of the latest scientific evidence from epidemiological data, the lower limit on the benchmark dose of inorganic arsenic for a 0.5 % increased incidence of lung cancer was determined to be 3.0 µg/kg body weight (210 µg in a 70-kg adult) per day (FAO/WHO 2010). Following the latest (period 2005–2010) estimation of fish consumption (13.9 g/day of fish for a 70-kg adult) by local authorities, when consuming the most polluted *Odontesthes bonariensis* (1.23 µg/g), a person would receive around 17 µg of As per day. This value is one order of magnitude lower than the lower limit mentioned above (Rosso et al. 2013).

However, considering these values a 60 kg person must consume more than 0.38-1.9 kg of silverside muscle from Chasicó per week to have health problems. Nevertheless this consumption rate may be actually lower in order to affect health since the BMDL values correspond to inorganic arsenic, which represents a small percentage of the total arsenic concentration (Avigliano et al. 2015).

Furthermore, the EFSA CONTAM Panel has established a Tolerable Weekly Intake (TWI) of 4 µg/kg bw for inorganic mercury which is in agreement with JECFA (FAO 2010). On this basis, a 60 kg person would have to consume more than 0.05 kg of silverside muscle from Chasicó Lake per week to obtain health issues. According to the EFSA (2010), the recommended maximum intake of Pb ranges from 4.34 to 29.4 µg/kg bw per week. Considering these values a 60 kg person would have to consume more than 1.5-9.3 kg of silverside muscle from Río de la

Plata per week to have health problems. In Argentina the average fish consumption rate (0.1-0.2 kg per week, FAO 2012) is similar to the rates calculated above for As and Hg in relation to silversides consumption from Chasicó Lake. However, the consumption rate is much lower than the calculated for Pb from Río de la Plata. The result can be specially severe for the lagoon-side and riverside communities which may consume greater amounts of fish leading to higher risk of chronic exposure to contaminants.

Furthermore, Vazquez et al. (2015) determined the Cr, Mn and Zn concentration in different tissues of silverside for Chascomús, Adela, Barranca, Chis-Chis and Tablilla pampasic lagoons. They found that levels of Cr, Mn and Zn in muscle exceed recommended limits by SCF, being dangerous for human consumption.

Particularly arsenic is present mainly as organic species in fish tissues. Water and food are the main sources of income of arsenic in fish. Arsenic concentrations in surface water in different body waters of Argentina were studied in the last decade (Schenone et al. 2007; Rosso et al. 2011; 2013; Puntoriero et al. 2014 a, b, c, 2015; Avigliano et al. 2015).

The relationship between the concentration of arsenic from water and different fish tissue is influenced by multiple factors. Some of these are environmental factors related to chemical aspects as the bioavailability of arsenic in water, its speciation, physicochemical parameters of water; and others are bio ecological aspects related to species (such as physiology, metabolism and detoxification processes, the story of evolutionary life of the species, type of prey on which it feeds, their patterns of migratory movements, among others).

This relationship is not direct and presents a large inter specific variability, so the results found for a given species could not be applied to another. Overall, this variability in arsenic concentrations in muscle of different fish species also occurs in marine fish. De Gieter and collaborators (2002) found in 25 species of marine fish from North Sea important differences in determined arsenic concentrations. The analysis of the results of these authors evidence that the higher values of arsenic in the muscle was present in species associated to the seabed as soles and rays. In the case of Pb, the presence of this element in water is caused mainly by the contribution of the activities of anthropogenic origin and from there they are bio transferred to the fishes through water and food.

The Hg has two origins in the Chaco-Pampean plain: anthropogenic origin related to industrial activity and natural origin, related to volcanic sediments (Avigliano et al. 2015).

Studies of toxicological risk from consumption of shad and silversides are limited having been studied health risk because organochlorine pesticides in silversides by Peluso et al. (2009) and the risk for metals by Rosso et al. (2013), Avigliano et al. (2015) and Vazquez et al. (2015). These last authors determined the risk for the consumption using the risk estimation equation USEPA or considering the guides intake values suggested by the same entity. Their findings concluded that consumption of these fishes in balanced diets would not be dangerous for human health. However, in the case of coastal or fishing populations where the diet is based on fish, there could be risk in the consumption. In this case monitoring is recommended to ensure the health of the population.

Discussion

The determination of metals in fishes has many challenges on which to move forward. We can mention the lack of studies about the presence of trace elements in the native species of the region of commercial importance; variability of methodologies applied in the determination of trace elements which difficult to compare results and follow the medium and long-term problems and limited works on bio transference of elements from the water and the preys to the fishes, among others.

These limitations generate weaknesses at the level of basic scientific and technological knowledge on the resources of the region since they generate socioeconomic problems as these commercial species are consumed in both internal and external markets. The increased work in this line of research will allow generate guidelines that promote this line and allow developing local capacities to train human resources, institutional strengthening of research and development centers, interdisciplinary work between academic-managers and fishermen. In this way the food security of local products was ensured.

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Table 1. Values of metals trace concentrations in muscle of commercial fishes.

Tabla 1 Valores concentraciones de metals traza en músculo de peces comerciales.

	As (mg/g)	Pb (mg/g)	Hg (mg/g)	Cd (mg/g)	Cr (ug/g)	Mn (ug/g)	Zn (mg/g)	Cu (mg/g)	Ni (mg/g)	References
(*Prochilodus lineatus*)										
Chascomús lagoon	0.16	0.76	-	<0.005	-	-	12.23	0.79	061	Schenone et al., 2014
Silversides (*Odontesthes bonariensis*)										
Río de la Plata Estuary	0.03 ± 0.03	0.19 ± 0.08	0.30 ± 0.06	0.01 ± 0.01	0.10 ± 0.05	0.32 ± 0.09	12 ± 2.9	-	0.07 ± 0.07	Avigliano et al., 2015
Adela Lagoon	0.05 ± 0.08	0.09 ± 0.09	0.04 ± 0.02	ND	0.09 ±0.03	0.35 ± 0.09	14 ± 4.2	-	0.07 ± 0.03	Avigliano et al., 2015
Barrancas Lagoon	0.04 ± 0.05	0.06 ± 0.19	0.03 ± 0.001	ND	0.05 ± 0.03	0.41 ± 0.03	12.6 ± 2.6	-	0.08 ± 0.06	Avigliano et al., 2015
Chasicó lake	0.08 ± 0.07	0.04 ± 0.03	0.42 ± 0.05	0.02 ± 0.02	0.04 ± 0.02	0.25 ± 0.04	18.4 ± 3.40	-	0.06 ± 0.03	Avigliano et al., 2015
Chasicó lake	0.03 - 0.01	-	-	-	-	-	-	-	-	Puntoriero et al., 2014
Quequén Salado River	1.23 ± 0.165	-	-	-	-	-	-	-	-	Rosso et al., 2013
Salado River	0.877 ± 0.381	-	-	-	-	-	-	-	-	Rosso et al., 2013
Sauce Grande Lake	1.013 ± 0.086	-	-	-	-	-	-	-	-	Rosso et al., 2013
Adela Lagoon	-	-	-	-	0.43 - 0.56	2.74 - 4.01	34.66 - 44.46	-	-	Vazquez et al., 2015

Table 1 (Continuation).

Tabla 1 (Continuación)

Barrancas Lagoon	-	-	-	-	0.64 - 1.117	4.14 - 8.73	33.07 - 50.59	-	-	Vazquez et al.
Chascomús Lagoon	-	-	-	-	0.52 - 1.44	2.10 - 17.26	28.12 - 88.46	-	-	Vazquez et al.
Tablilla Lagoon	-	-	-	-	0.40 - 1.00	1.72 - 13.45	86.23 - 123.65	-	-	Vazquez et al.
Chis Chis Lagoon	-	-	-	-	0.15 - 0.26	1.44 - 3.98	78.05 - 134.65	-	-	Vazquez et al., 2015
Maximum limit CAA	1	0.3	0.5		-	-	-	-	-	

ND: Not Detected.