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Is the shrimp *Macrobrachium amazonicum* sold in an urban center in the central Brazilian Amazon contaminated with microplastics?

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ABSTRACT

Growing global concern surrounds microplastics, found in various environments. However, data on microplastics contamination in salted shrimp and associated health risks remain scarce. We analyzed whether salted shrimps sold in markets in a main city in Amazonas state (Brazil), are contaminated with microplastics. We examined 150 specimens of *Macrobrachium amazonicum* and found 396 potential microplastics in 129 individuals (86%). The number of particles per gram of body mass was highest in the gastrointestinal tract, with 60% of them ranging in size from 1,000 to 5,000 µm, predominantly dark blue fibers (80%). The contamination likely originates from the environment and the salt used during processing in the region where the shrimps are captured. Our findings point to a potential health risk to the many consumers of salted shrimp in the Amazon region.

KEYWORDS: Crustacea, bioaccumulation, gastrointestinal tract, aquatic pollution

O camarão *Macrobrachium amazonicum* vendido em um centro urbano na região central da Amazônia brasileira está contaminado com microplásticos?

RESUMO

Há uma crescente preocupação global com os microplásticos, encontrados em diversos ambientes. No entanto, ainda faltam dados sobre a contaminação por microplásticos em camarão salgado e os riscos à saúde associados. Analisamos se os camarões salgados vendidos em mercados de uma cidade principal no estado do Amazonas (Brasil) estão contaminados com microplásticos. Examinamos 150 espécimes de *Macrobrachium amazonicum* e encontramos 396 potenciais microplásticos em 129 indivíduos (86%). O número de partículas por grama de massa corporal foi mais alto no trato gastrointestinal, com 60% delas variando em tamanho de 1.000 a 5.000 µm, predominantemente fibras de cor azul escura (80%). A contaminação provavelmente se origina do ambiente e do sal utilizado durante o processamento na região onde os camarões são capturados. Nossos resultados indicam um potencial risco à saúde para os muitos consumidores de camarões salgados na região amazônica.

PALAVRAS-CHAVE: crustáceos, bioacumulação, trato gastrointestinal, poluição aquática

Microplastics (MPs) are characterized by a size equal to or less than 5 mm (UNEP 2020) and are persistent environmental pollutants present in several environments (Morais *et al.* 2024). Due to their dispersion capacity, they occur in the water column of rivers, (Gerolin *et al.* 2020), including the Amazon (Guimarães *et al.* 2024). Aquatic organisms ingest MPs due to their similarity with natural food particles (Cruz *et al.* 2023) or have them adhered to their bodies (Azevedo *et al.* 2024). MPs may be transferred among trophic levels (Zhang *et al.* 2024). For example, shrimps can easily ingest MPs through their prey (Hossain *et al.* 2020), which are usually small arthropods, mollusks and juvenile fish (Devriese *et al.* 2015).

Considering the lack urban effluent treatment in the Amazon (Morais *et al.* 2024) and the presence of MPs in the salt that is used for food preservation (Vidyasakar *et al.* 2021), the contamination of salted native Amazonian

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shrimps by MPs is highly probable. Dried and salted shrimps, such as *Macrobrachium amazonicum*, are commonly sold in northern Brazil. Since shrimps are often consumed with the gastrointestinal tract intact, it is important to evaluate the presence of MPs in this organ. In this study, we determined the contamination by MPs in salted *M. amazonicum* sold in markets in the city of Itacoatiara, Amazonas state, Brazil.

We acquired 150 specimens of salted *M. amazonicum* of various sizes in 12 April 2021 from a single commercial wholesaler, who buys shrimps caught in lakes connected to the Amazon River in the Santarém region of Pará state. The shrimps are salted in Santarém before being marketed. Santarém has an estimated 331,942 inhabitants (IBGE 2022) and lacks adequate sewage treatment for 96.2% of the population (PSB 2022), contributing to MP presence in aquatic environments (Morais *et al.* 2024). The shrimps acquired in Itacoatiara were stored at -10 °C and later thawed for measurement. Total wet weight (g) and length (mm) were recorded using a scale and caliper, respectively. MPs were assessed in three body parts: gastrointestinal tract (GT), cephalothorax (CT) and abdomen (AB).

MPs were extracted through digestion, flotation and filtration, following Li *et al.* (2015), observed under a stereomicroscope (13× to 56×) and photographed with a digital camera (Moticam 2300, 3.0 MP). We recorded size (72–4598 µm), color and shape of each particle (UNEP 2020). Cross-contamination was avoided according to Hossain *et al.* (2020). As we did not determine the chemical composition of the MPs, the detected particles were classified as potential MPs, following the simplified protocol by Lusher *et al.* (2020).

The total number of potential MPs was divided by the number of shrimps to calculate the abundance of MPs per shrimp and by the total wet weight of each of the three body parts to determine the abundance per gram. The abundance and size of potential MPs met the requirements for parametric analysis and were compared among CT, GT, and AB using analysis of variance, followed by a Tukey post-hoc test. The relationship between the total length and wet weight of the shrimps and the total potential MPs per shrimp was assessed using Spearman's correlation. A significance level of 0.05 was used for all analyses. The analyses were conducted using RStudio Version 2024.4.1.748 (R Core Team, 2024).

Total length and wet weight of the shrimps ranged from 45 to 70 mm (mean 55.63 ± 4.65 mm), and 0.70 to 3.01 g (mean 1.53 ± 0.37 g), respectively. We detected 396 potential MPs in 129 of the 150 evaluated shrimps, ranging from 0 to 6 potential MPs per individual (average 2.64 ± 1.75 potential MPs per individual, N = 129 [86%]). Total wet weight ($r_{Spearman}$ = -0.068; $p > 0.05$; N = 150) and total length ($r_{Spearman}$ = 0.006; $p > 0.05$; N= 150) of shrimps were not significantly correlated with number of potential MPs per individual. The abundance of potential MPs differed significantly among body parts (F= 34,742; df= 2; $p < 0.05$), being significantly higher on GT (Table 1), despite the number of particles being higher in CT (Tables 2 and 3). Potential MP size did not differ significantly among body parts (F = 1.074; df= 2; $p > 0.05$). The majority of the potential MPs identified in the GT, CT and AB belonged to the size class of 1,000 to 5,000 µm (Table 2). MPs were classified into six colors (Table 3) and two shape types; fibers (88%) and fragments (12%) (Figure 1).

This is the first report on the presence of potential MPs in salted shrimps sold in the central Brazilian Amazon, with higher potential MP abundance than that reported in fresh shrimp (Guimarães *et al.* 2023). There are no specific regional guidelines for MP contamination regarding shrimp commercialization, yet our findings indicate the need for regulation, mainly considering that these shrimps are regularly consumed. The risk to human health can be strongly

Table 1. Minimum (Min), maximum (Max), and mean ± standard deviation (SD) abundance per gram (g) of potential microplastics (MPs) in body parts of *Macrobrachium amazonicum*. Different letters indicate significant difference between body parts.

Body part	**MPs abundance** (particles g^{-1})		
	Min	Max	Mean ± SD
Gastrointestinal tract	0	200	12.38 ± 22.79[a]
Cephalothorax	0	6.15	1.33 ± 1.32[b]
Abdomen	0	8.57	1.37 ± 2.03[b]

Table 2. Size range of potential microplastics found in the gastrointestinal tract (GT), cephalothorax (CT) and abdomen (AB) of *Macrobrachium amazonicum*.

Size (µm)	**Number of items**			**Relative frequency (%)**		
	GT	CT	AB	GT	CT	AB
72–250	11	23	5	8.59	13.14	5.38
250–500	12	15	5	9.38	8.57	5.38
500–1,000	28	43	16	21.88	24.57	17.20
1,000–4,598	77	94	67	60.16	53.71	72.04

Table 3. Color of potential microplastics found in the gastrointestinal tract (GT), cephalothorax (CT) and abdomen (AB) of *Macrobrachium amazonicum*.

Color	**Number of items**			**Relative frequency in body part (%)**		
	GT	CT	AB	GT	CT	AB
Dark blue	103	130	81	80.47	74.29	87.10
Red	12	19	4	9.38	10.86	4.30
Light blue	9	14	5	7.03	8.00	5.38
Dark green	3	9	2	2.34	5.14	2.15
Light green	1	3	-	0.78	1.71	-
Gray	-	-	1	-	-	1.08

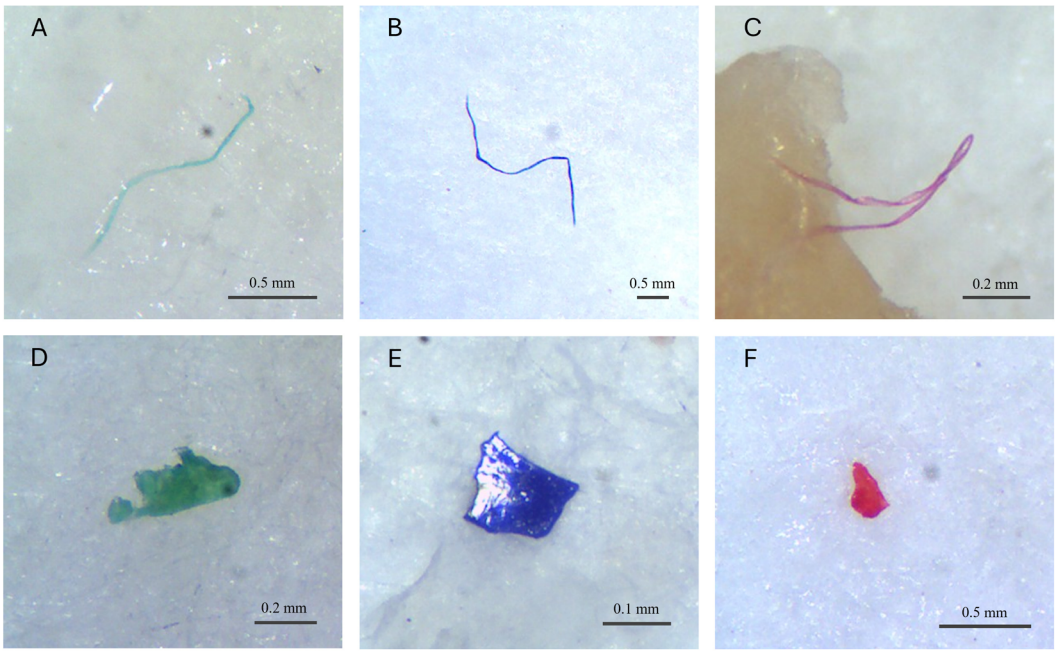

Figure 1. Characteristics of potential microplastics found in *Macrobrachium amazonicum*. A = light green fiber; B = dark blue fiber; C = red fiber; D = dark green fragment; E = dark blue fragment; F = red fragment.

influenced by particle size, with most potential MPs in the shrimp being larger than 1 mm, which increases the particles' ability to adsorb toxic contaminants (Lim *et al.* 2022) and cause physical damage to intestinal cells and gastrointestinal barriers in humans, potentially leading to more serious health issues (Lin *et al.* 2022).

The higher frequency of potential MPs in the gastrointestinal tract is possibly related to the lack of basic sanitation services in Santarém, which maximizes the release of MPs into the lakes where the shrimps are captured (Morais *et al.* 2024). Additionally, specific characteristics such as diet and habitat can influence MP levels (Keshavarzifard *et al.* 2021). Another shrimp species also contained a majority of particles > 1,000 µm in the GT (Hossain *et al.* 2020). The presence of blue and red fibers in our study suggests that the potential MPs originate from textile materials or fishing equipment, which are commonly used in the capture region (Guimarães *et al.* 2023; Oliveira *et al.* 2023; Morais *et al.* 2024). Also, *M. amazonicum* can confuse the colored particles with their natural food and consume them by mistake (Cruz *et al.* 2023).

The presence of potential MPs in the cephalothorax may be related to respiration in contaminated waters (Guimarães *et al.* 2023), as well as to the process of salting the shrimp. The salt used for preservation is a known source of MP fibers larger than 1,000 µm, often blue and red (Vidyasakar *et al.* 2021). This highlights the need to consider both internal and external contamination when assessing the risks associated with consuming salted shrimps.

The presence of potential MPs in the abdomen is of particular concern, as it is the consumable part of the shrimp, posing most risk due to the accumulation of these contaminants in food (Guimarães *et al.* 2023). Potential MPs in the AB cannot be translocated to the tail muscle due to their size (Devriese *et al.* 2015). The presence of MPs may also be related to the molting process of the shrimps, during which the animals change their mobility and behavior, possibly making them more vulnerable to these contaminants (Fan *et al.* 2022; Pichardo-Casales *et al.* 2024). To address this issue in the Amazon, it is crucial to implement public policies that improve plastic waste management, ensure proper wastewater treatment and promote monitoring of food contamination, as well as awareness of the risks involving the ingestion of MPs (Morais *et al.* 2024). Further studies should characterize the polymers that compose the MPs, to identify contamination sources, as well as increase the knowledge on the geographical scale of MP contamination in salted shrimps in the Amazon region.

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