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MICROPLÁSTICOS EM ALIMENTOS DE ORIGEM VEGETAL NA CIDADE DE ITACOATIARA (AM), BRASIL

ITACOATIARA
2025

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Trabalho de Conclusão de Curso apresentado ao Curso de Farmácia da Universidade Federal do Amazonas (UFAM), como requisito para obtenção do título de Bacharel em Farmácia.

Orientador: Prof. Dr. Bruno Sampaio Sant'Anna

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Microplastics in plant-based foods in the city of Itacoatiara (AM), Brazil

Microplásticos em alimentos de origem vegetal na cidade de Itacoatiara (AM), Brasil

Humberto Cesar Siqueira Staffen[1], *Gabriel dos Anjos Guimarães*[1], *Gustavo Yomar Hattori*[1], *Bruno Sampaio Sant'Anna*[1]

ABSTRACT

Microplastics are practically ubiquitous contaminants in all environments on the planet. Therefore, the present work aimed to investigate microplastic contamination in lettuce, chives, and cilantro sold in Itacoatiara, Central Amazon, Brazil. Samples of each vegetable were acquired from different commercial establishments. The samples were washed with filtered distilled water to remove any particles present on the surface of the vegetables. Hydrogen peroxide was added to the water used to wash the vegetables to digest organic materials. The solution was stirred daily and kept in an oven at 60°C. The microplastic particles were separated using the density difference technique. In total, 247 microplastic particles were recorded. There was no significant difference in the number of microplastic particles per sample of the three types of vegetables. The size of the microplastic particles also did not differ significantly between the types of vegetables, with the smallest (0.067 mm) and largest (4.865 mm) particles being found in lettuce. The proportion of microplastic colors recorded on the vegetables varied significantly. Blue and red particles were predominant, with a greater abundance of blue particles (n=207; 83.8%). There was a significant difference in the proportion of microplastic particle formats, with fibers (n=235; 95.1%) being more representative than fragments (n=12; 4.9%). Thus, it can be confirmed that the vegetables sold in Itacoatiara, Central Amazon are contaminated, consequently unsafe for direct human consumption, and require washing with plenty of running water to eliminate microplastic particles before being consumed fresh.

Keywords: contamination by plastic; plant foods; plastics in food.

RESUMO

Os microplásticos são contaminantes praticamente onipresentes em todos os ambientes do planeta. Portanto, o presente trabalho teve como objetivo investigar a contaminação por microplásticos em alface, cebolinha e coentro vendidos em Itacoatiara, Amazônia Central, Brasil. Amostras de cada vegetal foram adquiridas de diferentes estabelecimentos comerciais. As amostras foram lavadas com água destilada filtrada para remover quaisquer partículas presentes na superfície dos vegetais. Peróxido de hidrogênio foi adicionado à água usada para lavar os vegetais para digerir materiais orgânicos. A solução foi agitada diariamente e mantida em estufa a 60°C. As partículas de microplástico foram separadas usando a técnica de diferença de densidade. No total, 247 partículas de microplástico foram registradas. Não houve diferença significativa no número de partículas de microplástico por amostra dos três tipos de vegetais. O tamanho das partículas de microplástico também não diferiu significativamente entre os tipos de vegetais, com as menores (0,067 mm) e as maiores (4,865 mm) partículas sendo encontradas na alface. Houve diferença significativa na proporção de cores de microplástico registradas entre os vegetais. Partículas azuis e vermelhas foram predominantes, com maior abundância de partículas azuis (n=207; 83,8%). Houve diferença significativa na proporção de formatos de partículas microplásticas, sendo as fibras (n=235; 95,1%) mais representativas que os fragmentos (n=12; 4,9%). Dessa forma, pode-se confirmar que há contaminação em vegetais comercializados em Itacoatiara, Amazônia Central, que estes não são seguros para consumo humano direto e que necessitam de lavagem com água corrente em abundância para eliminação de partículas microplásticas antes de serem consumidos frescos.

Palavras-chave: contaminação por plástico; alimentos vegetais; plásticos em alimentos.

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Introduction

Plastic was first synthesized in England in the 1850s and is now widely used in all aspects of everyday life (Yao et al., 2022). Over the past decades, materials containing plastic have been used in all sectors of production and human life and have gradually become indispensable, replacing the traditional due to its lightweight, durability, and lower cost (Patel et al., 2022).

In contrast, the durability of plastics is remarkable, and their short service life leads to the increasing accumulation of plastic waste in the environment (Mong et al., 2024). Based on recent projections, global municipal solid waste generation is expected to increase from approximately 2.3 billion metric tons in 2023 to 3.8 billion metric tons by 2050 (Fayshal, 2024). This problem is worse in developing countries like Brazil, which was responsible for dumping 940,540 tons of waste into the Atlantic Ocean between 2010 and 2020 (Chassignet et al., 2021), and only 1.28% of the plastics were recycled (Fundação Heinrich Böll, 2020; Almeida et al., 2021).

Even though the use of plastic has revolutionized the world, the elimination of much of the waste generated is still problematic, and it is often dumped unprocessed into the environment (Lebreton and Andrady, 2019; Kedzierski et al., 2020). It is estimated that 181 million tons of plastic waste were inappropriately discarded in the environment by 188 countries in 2015 (Lebreton and Andrady, 2019); approximately 8–10 million metric tons of plastic waste enter the oceans annually (Thiagarajan and Devarajan, 2025) and 142 million tons are stored in the oceans (Horton, 2022). As a result of poor management of appropriate disposal, the fragmentation of these materials becomes inevitable, which increases the problems caused in the oceans (George et al., 2024) and in other environments where irregular disposal occurs, such as forests. As such, plastic particles end up being dispersed throughout the environment (Cunningham and Sigwart, 2019).

The negative effects generated by plastic waste are increasing, both for biota health and the environmental equilibrium (Baruah et al., 2022). One of the most worrying factors is the length of time for its decomposition and resistance to degradation (Bancone et al., 2020), and depending on the type of polymer it is made from, it can persist in the environment for centuries (Chamas et al., 2020). Furthermore, microplastics are distributed across different types of agricultural land (Athavuda et al., 2025), with an emphasis on intensive agricultural activities including fertilization, mechanized cultivation and harvesting, which substantially increases the input of microplastics from the soil (Chen et al., 2025). With dimensions on the scale of millimeters, microplastics are difficult to detect and, for this reason, contamination of environments, water sources, and even commercial products often goes undetected. As a result, many contaminated products continue to be part of human consumption (Cox et al., 2019). Some studies indicate that micro/nanoplastics may present acute toxicity, (sub)chronic toxicity, carcinogenicity, genotoxicity, and developmental toxicity (Yuan et al., 2022). In animals, ingested microplastics accumulate in the body, enter other tissues around the gastrointestinal tract, causing intestinal damage and disrupting energy flow, affecting the survival, growth, and development of the organism (Wu et al., 2024).

Nutrient-rich sewage sludge is used as an organic fertilizer in the United States and Europe and, as a result of this practice, European farmlands can be considered the largest global reservoir of microplastics (Lofty et al., 2022). Kedzierski et al. (2023) estimated that around the world between 1.5 and 6.6 million tons of microplastics are stored in agricultural soils and that the distribution between countries is probably not uniform. The source of contamination of agricultural soils can be of different origins, coming from sludge added as fertilizer (Lofty et al., 2022), of air (wind) (Bullard et al., 2021; Rezaei et al., 2022), and agricultural activity itself (Isari et al., 2021) such as irrigation (Kundu et al., 2022; Guo et al., 2023; Liu et al., 2023), irregular waste storage (Liu et al., 2018), and gradual decomposition of larger plastic materials as plastic mulch and greenhouse films (Wang et al., 2022; Guo et al., 2023; Sa'adu and Farsang, 2023). As we can see, contamination of agricultural land by microplastics is a sad reality. Therefore, the present study aimed to investigate microplastic contamination in vegetables (lettuce, chives, and cilantro) grown and sold in Itacoatiara, Central Amazon, Brazil.

Material and Methods

Acquisition and processing of samples

The vegetable samples were acquired from different commercial stores in Itacoatiara, Central Amazon, Brazil (3º8'19.9" S; 58º27'32.5" W). These vegetables were produced on small rural properties that surround the urban area of the municipality. In total, 30 samples of each investigated vegetable were acquired: lettuce (*Lactuca sativa*; Linnaeus, 1753), chives (*Allium schoenoprasum*; d'Argeville, 1753), and cilantro (*Coriandrum sativu*; Lindley, 1836), totaling 90 samples. The vegetables were transported in sealed packaging provided by commercial establishments and taken to the laboratory for analysis.

The vegetables were acquired already packaged by the store and, when transported, the packaging was checked for sealing to avoid contact with the air of the urban environment. The packages containing the vegetables were only opened in the laboratory during sample preparation. Considering that the packaging itself could contaminate the samples, its cut or breakage was avoided by always opting to untie the tie that sealed the packaging.

In the laboratory, the roots of the plants were removed with the help of a metal knife and discarded. The leaves of each sample were carefully washed with filtered distilled water (500 mL) and the water with residues was collected in a beaker previously sanitized with filtered distilled water. To digest any organic material present in the sample, 500 mL of a 30% (v/v) hydrogen peroxide (H_2O_2) solution was added. The resulting solution was stirred three times a day and kept in an oven at 60°C for 96 hours. To separate the microplastic particles by density, the samples were mixed with the same volume of saturated sodium chloride solution (1.2 g/cm³ of NaCl) and stirred manually with the help of a glass rod. After this procedure, 80% of the solution was vacuum filtered using qualitative filter paper 9.0 cm, 250 g (pore size 5 μm) to retain microplastic particles. This procedure of adding and mixing saturated saline and vacuum filtration was repeated two more times to ensure the extraction of the maximum number of microplastic particles. After filtering, the filter paper was placed in a labeled Petri dish for oven drying at 60°C for 48 hours.

The samples on each filter paper were analyzed using an image analysis system that consists of a Leica EZ4 stereomicroscope with magnifications from 13x to 56x coupled to a Moticam 2300 3.0 megapixel camera, connected to a computer with Motic Images Plus 2.0 ML program. Using this program, the microplastic particles were measured (mm) and classified according to color, shape, and type according to EU Marine Strategy Framework Directive (MSFD Technical Group on Marine Litter et al., 2023).

Quality control

To ensure that samples were not contaminated in the laboratory, all the glassware were washed with distilled water previously filtered in a vacuum system with filter paper (pore size 5.0 μm). Before the analyses, the bench and all materials were also carefully cleaned. The samples were left uncovered for a few minutes during preparation and filtering. When washing the vegetables, gloves and metal tongs were used to avoid direct contact with the samples. Once prepared, the samples were covered with aluminum foil and placed in a drying oven. The air conditioning remained off during all procedures to prevent air circulation in the laboratory. After filtering the samples, the prepared Petri dishes were also covered with aluminum foil. The use of plastic-based materials and equipment was avoided.

To ensure no contamination from the air in the laboratory, 15 Petri dishes with filter paper (pore size 5 μm) were exposed on the bench for the same time that the samples were uncovered during washing and filtering the samples (20 minutes). The filters were analyzed and no microplastics were observed.

Statistical analyses

The average number of microplastic particles per sample and the average particle size were compared between the three types of vegetables using the Kruskal-Wallis (KW) non-parametric analysis of variance. The proportion of shapes and colors recorded in the samples of the three vegetables was compared using the X^2 test and contingency table. For both tests, a significance level of $p<0.05$ was adopted.

Results

In total, 247 microplastic particles were identified in the three vegetables investigated. The most contaminated vegetables were chives followed by lettuce, with 95 and 90 particles, respectively; cilantro had 62 microplastic particles.

The number of particles per sample varied from 0 to 9; however, the average number of microplastic particles per sample was similar among the vegetables (Figure 1). Lettuce and chives more frequently showed contamination (90.0% in each) while cilantro showed a lower frequency (76.6%). There was no significant difference in the number of particles per sample between vegetables (KW=4.0985; p=0.1288).

The smallest and largest microplastic particles were recorded in lettuce, 0.067 and 4.865 mm in length, respectively. The size of the microplastic particles did not differ significantly between the vegetables investigated (KW= 5.4342; p=0.066) (Figure 2).

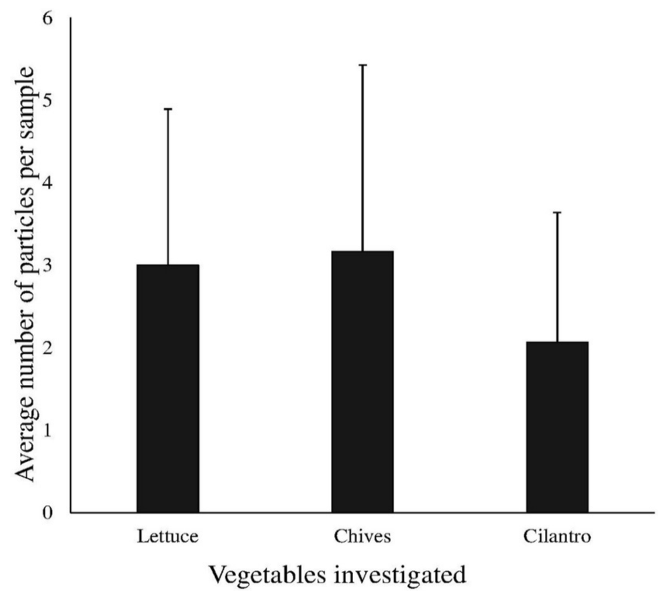

Figure 1 – Mean and standard deviation of the number of microplastic particles per sample of lettuce, chives, and cilantro sold in Itacoatiara, Amazonas, Brazil.

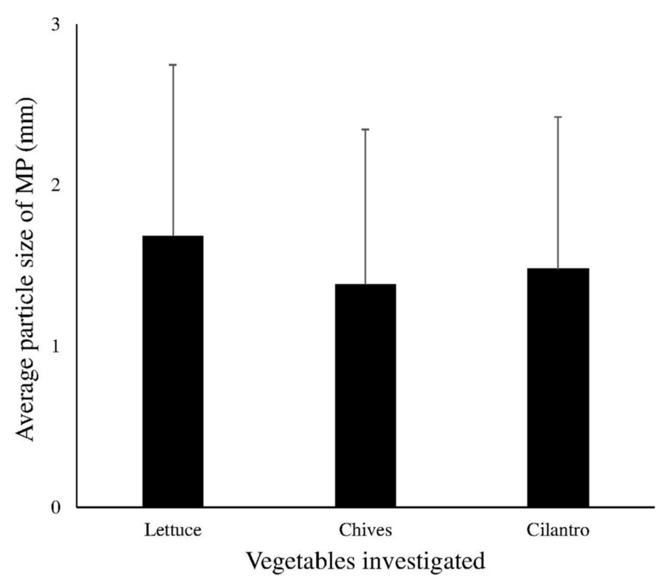

Figure 2 – Mean and standard deviation of microplastic particle size (mm) in each type of vegetable sold in Itacoatiara, Amazonas, Brazil.

A significant difference in the proportion of colors of microplastic particles (χ^2=13.579; $p<0.05$) was found. The main colors recorded among the 247 microplastic particles were blue and red, totaling 95.5% of the samples (Figure 3). In a smaller percentage, white microplastics were recorded (n=5; 2%), as well as purple (n=3; 1.2%), gray (n=1; 0.4%), green (n=1; 0.4%), and transparent (n=1; 0.4%). Of the total particles recorded, 235 had the shape of fibers (95.1%), and 12 were fragments (4.9%) (Figures 4 and 5). There was a significant difference in the proportion of the shapes of the microplastic particles (χ^2=4.859735; $p<0.05$).

Discussion

With intensive agricultural practices, an increased use of plastic may be expected, leading to increased contamination and greater exposure (Beriot et al., 2021). All the vegetables examined in the present study showed contamination by microplastics; lettuce and chives were the most contaminated, which may be related to the larger surfaces of these vegetables than cilantro. As already noted, microplastic particles can be transported to the soil in different ways (Isari et al., 2021; Sridharan et al., 2021; Zhao et al., 2022), and plastic mulch used to cover the soil may be one of the main sources of agricultural soil contamination (Khan et al., 2023). Microplastics are transferred to humans through the food chain by consuming contaminated food (Aydin et al., 2023) as detected in essential foods such as drinking water (Bäuerlein et al., 2022), table salt (Zhang et al., 2020), and vegetables (Kadac-Czapska et al., 2022). In general, microplastics infiltrate the circulatory system through three main routes: inhalation, ingestion, and skin contact (Kutralam-Muniasamy et al., 2023). However, the presence of microplastics in vegetables can be minimized by washing, and the use of edible detergent is more effective in comparison to other washing methods, such as rinsing with water and cleaning with ultrasonic vibration (He et al., 2023). Avoiding the ingestion of microplastic particles as much as possible is very important, as the relevance of microplastics for food safety is still subjective, considering that the toxicity of microplastics depends on their co-contaminants, chemical additives, and adsorbed microbial population (Xu et al., 2025).

No significant difference was observed between the vegetables regarding the number of microplastic particles per sample. This result may be associated with other sources of contamination of vegetables by microplastics, such as in the packaging, transportation, or marketing process. According to Sobhani et al. (2020), opening plastic packaging can generate microplastics, regardless of the approach used to open the packaging and the type of plastic. Conti et al. (2020) determined the contamination by microplastics in five vegetables commonly consumed in Italy, with carrots being the most contaminated, while lettuce was the least contaminated sample. Comparing contamination in lettuce grown in gardens in rural and urban areas and those sold in supermarkets, Canha et al. (2023) observed that plants grown in gardens in urban or rural areas showed similar contamination, but lettuce grown in gardens showed 70% more contamination than lettuce sold in supermarkets. The results of the present study indicate that there is no general pattern for contamination in vegetables sold in Itacoatiara in the Central Amazon, as the dispersion of microplastics can occur irregularly and from multiple sources, and not necessarily in a standardized and homogeneous manner.

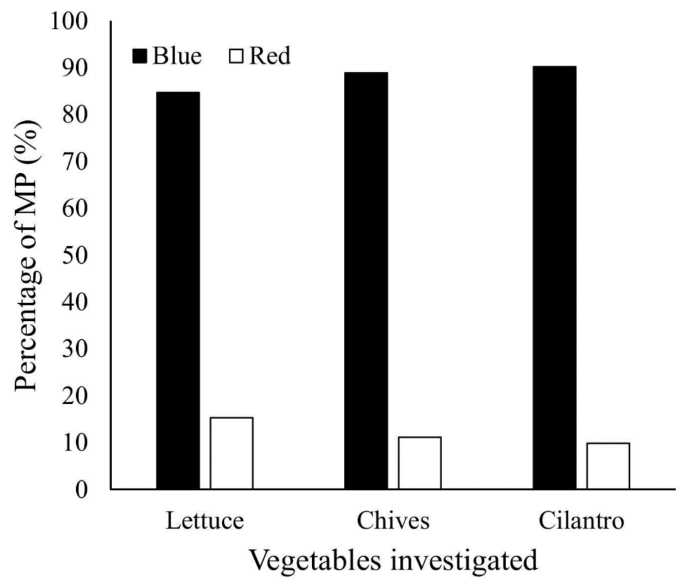

Figure 3 – Percentage of blue and red microplastic particles recorded in the three types of vegetables sold in Itacoatiara, Amazonas, Brazil.

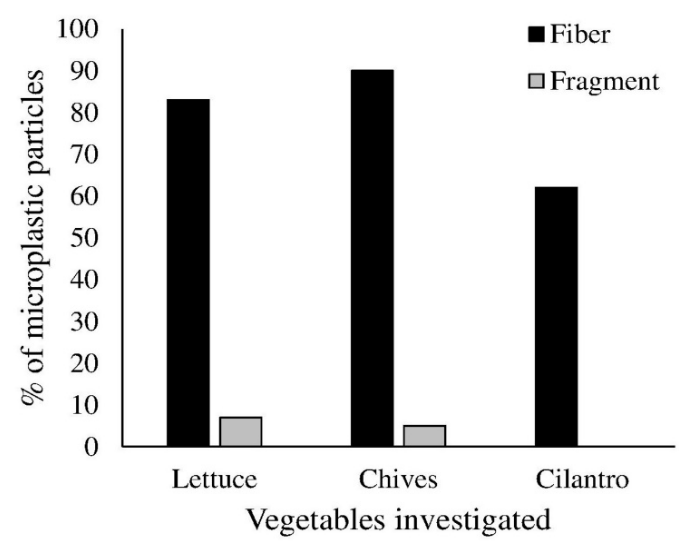

Figure 4 – Percentage of microplastic particles found in the vegetables lettuce, chives, and cilantro in the format of fibers (black) and fragments (gray).

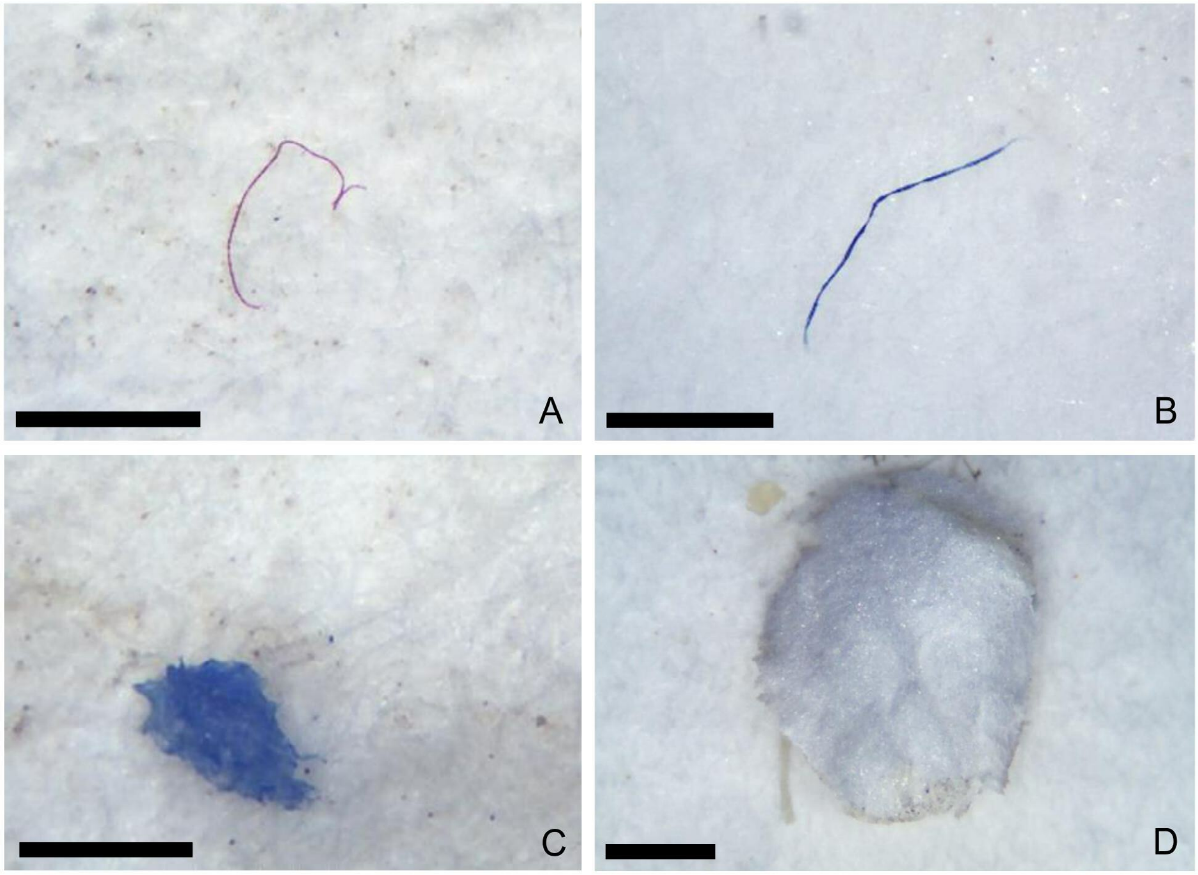

Figure 5 – Microplastic particles recorded in samples of lettuce, chives, and cilantro ([A] red fiber; [B] blue fiber; [C] blue fragment; and [D] white fragment). Scale bar=1 mm.

The size of microplastic particles recorded on the vegetables showed no significant difference, which indicates contamination by particles with similar characteristics. Gerolin et al. (2020) evaluated microplastic contamination in sediment samples collected in the Amazon, Negro and Solimões Rivers, upstream and downstream of the metropolitan region of Manaus, and recorded a variation in size ranging from 0.0630 to 5.000 mm in length. In addition, freshwater areas used for bathing around Itacoatiara were also contaminated by microplastics (Oliveira et al., 2023) with sizes ranging from 0.0150 to 4.909 mm. This is an indication of one of the possible sources of contamination of vegetables in the present study, as water from the region's rivers is used for irrigation in local agriculture.

In this work, blue and red particles were the most frequently recorded colors. These were also observed in the study by Aydin et al. (2023) on vegetables but in less abundance. The color of the particles may be related to the different sources of contamination, as recorded by Guimarães et al. (2023) who investigated contamination of the shrimp *Macrobrachium amazonicum* (Heller, 1862) in the same region as this study. In the sediments of rivers in the region, Gerolin et al. (2020) observed the abundance of white particles, followed by blue, black, and red, which indicates there is no defined pattern and also highlighted the presence of heavy metals, which are used to color microplastic particles. Although Hartmann et al. (2019) do not consider color crucial in a categorization framework, it may make sense to include it as an additional descriptor, since it is useful for identifying potential sources even though they are subject to discoloration by particle wear itself.

Fibers were the particles that most predominated in the samples. This is in accordance with the study carried out by Guimarães et al. (2023), who analyzed the presence of microplastics in freshwater shrimp (*M. amazonicum*), and Oliveira et al. (2023), who analyzed the areas used for bathing in the same region. In their study on the widespread distribution of microplastics at shallower depths near sandy beaches in the Amazon (Martinelli-Filho and Monteiro, 2019), the authors obtained a relatively high frequency of plastic fibers, demonstrating that there may be a predominance of fiber-shaped microplastics in the region. According to Kwon et al. (2020), the percentage of fiber found in several of the foods analyzed is greater than 50%, with all sea salt samples presenting fibers (see the review of Kosuth et al., 2018), though in lake salts this fraction is reduced (<20%) (Kim et al., 2018).

Conclusion

The results of this study corroborate the hypothesis that vegetables in Itacoatiara, in the interior of the state of Amazonas, are sold despite being contaminated by microplastic particles and thus are not safe for direct human consumption. Contaminated samples were acquired in all commercial locations, demonstrating that microplastic contamination is not just an isolated case. It was also shown that there is no difference in the quantity and size of microplastic particles between the vegetables. To minimize the ingestion of microplastics present in these foods, rigorous washing with running water is recommended so as to eliminate any particles as well as adequate storage in containers not made of plastic.

Authors' contributions

Staffen, H.C.S.: formal analysis, acquisition, investigation, writing – original draft, writing – review & editing. **Guimarães**, G.A.: writing – original draft. **Hattori**, G.Y.: writing – original draft. **Sant'Anna**, B.S.: conceptualization, supervision, writing – original draft, writing – review & editing.

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