Quantification of Microplastics in Plastic-Bottled Chinese Baijiu Using Micro-FTIR in Imaging Mode

Xuejun Zhou *, Qian Wang, Jin Wang, Hongyan Li, Jiefang Ren and Shali Tang

Zhejiang Institute of Science and Technology for Product Quality and Safety, Hangzhou 310018, China
* Correspondence: zhouxj@zjzay.com

Abstract: Microplastics (MPs) are prevalent in our environment, being present in the air we breathe and in the food we consume. Due to the widespread use of plastic materials in everyday life, the amount of microplastics being released into the biosphere has become increasingly apparent in recent years. This study provides the first documentation of the presence of microplastics in Chinese baijiu, a popular alcoholic beverage in China, bottled in plastic. It is essential to note the significance of this discovery and potential implications for human health. Analysis of samples collected from the Chinese market showed the presence of microplastics in all six Chinese baijiu brands tested. Concentrations ranged from 172 MPs/500 mL to 944 MPs/500 mL with an average concentration of 436 MPs/500 mL. Cellulose and PA accounted for 70.4% and 17.8% of all microplastics detected, respectively. These were the most commonly detected types. Other types of microplastics were also found, including PET, PP, PVC, and PE. PET accounted for 2.7%, PP for 2.2%, PVC for 1.2%, and PE for 0.1% of all microplastics. The possible sources of contamination include raw materials, ambient air, and equipment and vessels that shed microplastics. Therefore, this study emphasizes the requirement for further research to mitigate the potential hazards associated with human exposure to microplastics. Additionally, it presents significant findings on the presence of microplastics in Chinese baijiu sold in plastic bottles.

Keywords: microplastics; plastic-bottled Chinese baijiu; micro-FTIR; imaging mode; pollution monitoring

1. Introduction

The pollution caused by microplastics has emerged as a global environmental problem, with their presence being detected in a range of aquatic environments [1]. Additionally, microplastics have been identified in drinking water and food, carrying a constant risk of exposure to humans [2–10]. The definition of microplastics, according to the European Food Safety Authority (EFSA) and the European Commission Recommendation, is a collection of materials with varying shapes and sizes such as fragments, fibers, spheroids, granules, pellets, flakes, and beads. Their size ranges from 0.1 to 5 mm, and they can be easily consumed by aquatic organisms, posing threats to their health and well-being as well as human health.

Alcoholic beverages packaged in plastic containers could potentially yield microplastics, given that these particles may seep into the liquid during production, transportation, and storage. Therefore, it is imperative to scrutinize the number, shape, and chemical composition of microplastics present in alcoholic drinks packaged in plastic bottles. Alcoholic beverages, such as wine, beer, and spirits, are popular and globally consumed. The size of the worldwide spirits market was approximately USD 467.69 billion in 2022, which equates to approximately RMB 3.3 trillion. According to global alcohol consumption records, spirits such as grain alcohol account for 45% of alcohol consumption, followed by beer at 15%, wine at 12%, and other alcohols at 28%. China’s liquor sales of RMB 662.6 billion have exceeded the global whisky sales of RMB 560 billion, making China the leading market...
of spirits and alcohol worldwide. Research reported in the Lancet [11] indicates that from 1990 to 2017, there was a global increase in per capita consumption of alcohol by adults from 5.9 L (95% CI: 5.8–6.1) to 6.5 L (6.0–6.9). It is projected that this figure will reach 7.6 L (6.5–10.2) by 2030. China’s per capita alcohol consumption stands at 10.61 L annually, with men consuming 13.68 L, significantly surpassing the global average of 6.1 L.

With the growth of the global economy, alcohol consumption has increased, leading to the expansion of the marketplace. Recent research has highlighted the need for thorough evaluation of human exposure to microplastic particles found in various alcoholic beverages, including spirits, wine, and beer. Smaller particles in the micro- or millimeter range have been the main focus of attention. For example, Liebezeit and Liebezeit (2014) [12] found microplastics in German beer, with concentrations ranging from 2 to 79 fibers per liter, from 12 to 109 fragments per liter, and from 2 to 66 granules per liter. Kosuth et al. (2018) [13] found microplastics in American beer, with levels varying from 0 to 14.3 MPs/L. Shruti et al. (2022) [14] identified microplastics in different Mexican beer brands, with concentrations ranging from 0 to 28 ± 5.29 MPs/L. Furthermore, Cox et al. (2019) [15] discovered that alcohols had an average microplastic content of 32.27 MPs/L, predominantly in the form of granules, films, foams, filaments, fibers, and fragments. Prata et al. (2020) [16] identified microplastic levels ranging from 2563 to 5857 MPs/L in white wine. The microplastics’ size was 0.1 µm, and their levels were lower than those observed in beer (0.8–6700 µm).

Chinese baijiu is an alcoholic beverage that is well-known in China and is typically derived from grains like wheat, rice, or barley. In recent years, numerous renowned Chinese liquor brands, headed by Moutai, have secured top positions among the world’s leading spirits brands and become world leaders in the spirits industry. Nevertheless, there is concern around the use of plastic bottles in the production and disposal of this popular beverage, as it may lead to the introduction of microplastics. Surprisingly, currently, there is a lack of knowledge concerning the extent of the presence of microplastics within plastic-bottled Chinese baijiu. To address this knowledge gap, our investigation sought to measure the levels of microplastics within Chinese baijiu stored in plastic bottles, using micro-FTIR (Fourier transform infrared) spectrometry in imaging mode.

Micro-FTIR is a widely accepted technique for detecting and identifying microplastics in complex matrices such as food and beverages. In imaging mode, micro-FTIR makes it possible to characterize microplastics in terms of their size, shape, and chemical composition. This information is valuable in identifying potential sources of microplastics and assessing their possible impact on food and beverages.

Currently, there is no specific legislation concerning micro- and nanoplastics as contaminants in food. As a result, the risks to human health from dietary exposure to these particles are still not well understood. When assessing the associated risks, several data gaps must be addressed. Hence, our study aimed to assess the levels and categories of microplastics found in plastic-bottled Chinese baijiu and explore the potential hazards linked to these particles in the context of wine drinking.

The results of our research hold considerable weight for the creation of tactics to diminish the emission of microplastics into surroundings and safeguard the security of the food supply chain. This knowledge is imperative for buyers, governing bodies, and the food sector in equal measure. By highlighting the presence and possible hazards of microplastics in Chinese baijiu bottled in plastic, our research contributes to the general comprehension of food contamination with microplastics, emphasizing the significance of implementing efficient steps to tackle this matter.

2. Materials and Methods
2.1. Sampling and Sample Preparation

Eighteen samples were collected, each comprising plastic-bottled Chinese baijiu from six distinct brands. The samples were purchased in triplicate from different local supermarkets in Hangzhou city, China. The bottles used for packaging the baijiu were made of PET
and ranged in volume from 5 L to 2.5 L (please refer to Table 1 for additional details). To avoid batch bias in the sample set, triplicate samples were collected from different stores. Milli-Q water was used as a blank for the sample. The integrity of microplastic particles was preserved, and the potential for degradation was minimized by storing the samples in a cool and dark environment prior to analysis.

Table 1. Characteristics of six bottled Chinese baijiu samples tested in this study.

<table>
<thead>
<tr>
<th>Brand</th>
<th>Alcohol by Volume</th>
<th>Volume</th>
<th>Packaging Tape</th>
<th>Manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>RedStar Erguotou Liquor (HX)</td>
<td>62%</td>
<td>5 L</td>
<td>PET</td>
<td>Beijing Red Star Company Limited (Beijing, China)</td>
</tr>
<tr>
<td>Mao Pu Pure grain wine (MP)</td>
<td>50%</td>
<td>5 L</td>
<td>PET</td>
<td>JinPower Company Limited. (Huangshi, Hubei Province, China)</td>
</tr>
<tr>
<td>Niu Lan Shan Erguotou Liquor (NLS)</td>
<td>52%</td>
<td>5 L</td>
<td>PET</td>
<td>Beijing Shunxin Agriculture Company Limited Niulanshan Distillery (Beijing, China)</td>
</tr>
<tr>
<td>Hui Yi Erguotou Liquor (HY)</td>
<td>52%</td>
<td>5 L</td>
<td>PET</td>
<td>Beijing Jianguo Brewery (Beijing, China)</td>
</tr>
<tr>
<td>Chun liang Liquor (CLYJ)</td>
<td>52%</td>
<td>2.5 L</td>
<td>PET</td>
<td>Luzhou Luqi Wine Industry Company Limited (Luzhou, Sichuan Province, China)</td>
</tr>
<tr>
<td>Bu Lao Tan grain wine (BLT)</td>
<td>52%</td>
<td>2.5 L</td>
<td>PET</td>
<td>Sichuan Bu Lao Tan Wine Company Limited (Luzhou, Sichuan Province, China)</td>
</tr>
</tbody>
</table>

2.2. Microplastic Extraction

A modified protocol, based on the methodology developed by Zhou et al. [17], was utilized for microplastic extraction from Chinese baijiu. To prevent background contamination, the researchers wore clean cotton lab coats and nitrile gloves during the study. The samples were processed on a laminar flow bench to minimize the risk of airborne contamination during the extraction process. The extraction process entailed microfiltration, succeeded by organic matter decomposition employing hydrogen peroxide, and consecutive continuous rinsing with deionized water.

Initially, 500 mL of each Chinese baijiu sample was filtered using a gold-plated polycarbonate membrane (25 mm in diameter) with a pore size of 0.4 µm, following a 90 min reaction at room temperature with a 30% (w/v) hydrogen peroxide (H₂O₂) solution to oxidize all natural organic matter. Following filtration, the filter membranes were transferred to lidded glass dishes and dried at room temperature before being stored for future analysis. To prevent potential procedural contamination, the control groups (glass beakers) underwent the same treatment.

2.3. Micro-FTIR Analysis

A Thermo Scientific Nicolet iN10MX micro-FTIR spectrometer (Madison, WI, USA) with a focal plane array (FPA) detector was used to conduct the microplastic analysis. Spectra of the microplastics were collected in imaging mode between 700 to 4000 cm⁻¹ at a resolution of 8 cm⁻¹. The FPA detector allowed for chemical images of the microplastics to be acquired, which provided information on their size, shape, and chemical composition. Omnic Picta spectrum imaging software was utilized for both image processing and analysis. To take the size of the instrument grating into consideration, the filter scan was separated into four sections employing identical settings. Subsequently, the images of all areas were merged to form a pseudocolor image to capture the spectra of all the particles deposited on the filter.

2.4. Microplastic Identification and Quantification

The identification and quantification of microplastics were carried out based on their distinct infrared spectra. The spectra were compared to Thermal Fisher Scientific’s infrared
spectral databases containing known microplastics such as cellulose, PA, PU, PE, PP, PS, PVC, and PET. A calibrated scale bar was employed to estimate the size of the microplastics from the chemical images using the longest dimension. The microplastic concentration in the Chinese baijiu samples was determined by counting the number of particles per milliliter of sample.

2.5. Quality Control Measures

Various quality control procedures were employed to ensure the precision and accuracy of the findings. To assess the risk of contamination during the extraction and analysis processes, blank samples were prepared and evaluated alongside the Chinese baijiu samples. Moreover, a reference material having a known microplastic content was appraised to verify the precision of the micro-FTIR method. The instrument was calibrated on a daily basis with a standard polystyrene film. Additionally, the results were confirmed by conducting a repeat analysis of a subset of samples.

2.6. Statistical Analysis

The results obtained from the infrared instrument were imported into MATLAB 2014a for statistical analysis. To evaluate the similarity between the sample spectral curve and the standard spectral curve, the Pearson correlation coefficient was employed. A substance match of 70%, as suggested by the literature [18], was regarded as indicative. In cases where sample components were complicated, manual spectral comparison was executed to verify qualitative outcomes. Spectral images ranging from 717–2000 cm\(^{-1}\) were chosen to calculate Pearson correlation coefficients between each pixel point’s spectra and the standard spectra. To assess microplastic presence, an experimental threshold of 0.7 was set, with values exceeding this value being indicative of the substance’s presence. The quantity of microplastics was estimated by quantifying the number of pixel points. The resulting data provided final statistics on microplastic content in Chinese baijiu.

2.7. Estimation of Human Uptake of Microplastics

The presence of microplastics in alcoholic drinks raises concerns regarding potential health effects despite exact impacts not being completely understood. To approximate the daily ingestion of microplastics due to alcohol consumption, a blend of experimental data from six brands of alcohol bottled in plastic were investigated. The estimated annual intake (EAI) of microplastics was calculated utilizing the following formula:

\[
EAI (\text{MP/y}) = (C \times \text{IR})
\]

where IR represents the intake rate (L/y) and C is the concentration of microplastics (MPs/L).

3. Results

3.1. Microplastic Abundance

The presence of microplastics in plastic-bottled Chinese baijiu, as shown in Figures 1–3, raises concerns regarding consumer health. The abundance of microplastics in plastic-bottled Chinese baijiu and Milli-Q water as a blank sample is presented in Table 2. Each sample was tested three times. All six plastic-bottled Chinese baijiu samples investigated in this study exhibited microplastic contamination. The mean microplastic concentrations varied from 173 MPs/500 mL to 944 MPs/500 mL. The relative standard deviation (RSD) for the six brands of plastic-bottled Chinese baijiu were as follows: BLT—0.029%, MP—0.084%, NLS—0.087%, HX—0.161%, HY—0.124%, and CLYJ—0.051%. These findings exhibit the satisfactory repeatability of the focal plane array-based micro-Fourier transform infrared (micro-FTIR) validation and data analysis technique.
Figure 1. Microplastic abundance of six brands of plastic-bottled Chinese baijiu (items/500 mL).

Figure 2. Microplastic abundance of six brands of plastic-bottled Chinese baijiu (items/500 mL) with standard deviations shown.

Figure 3. Polymer content of microplastics from Chinese baijiu in plastic bottles.
### Table 2. Microplastic abundance of six brands of plastic-bottled Chinese baijiu (items/500 mL).

<table>
<thead>
<tr>
<th>Sample</th>
<th>Average Microplastic Abundance (Items/500 mL)</th>
<th>Total Microplastic Abundance (Items/500 mL)</th>
<th>RSD (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bu Lao Tan grain wine (BLT)</td>
<td>Cellulose 147, PET 41, PS 68, PU18, PA 125, PVC 11</td>
<td>410</td>
<td>422 398</td>
</tr>
<tr>
<td>Mao Pu Pure grain wine (MP)</td>
<td>Cellulose 833, PET 9, PU3, PA 56, PVC 43</td>
<td>942</td>
<td>1024 866</td>
</tr>
<tr>
<td>Niu Lan Shan Erguotou Liquor (NLS)</td>
<td>Cellulose 214, PET 16, PU14, PA 31, PVC 1</td>
<td>274</td>
<td>252 300</td>
</tr>
<tr>
<td>RedStar Erguotou Liquor (HX)</td>
<td>Cellulose 89, PU17, PA 61, PVC 5, PP 1</td>
<td>178</td>
<td>143 198</td>
</tr>
<tr>
<td>Hui Yi Erguotou Liquor (HY)</td>
<td>Cellulose 172, PET 8, PU10, PA40, PVC 1, PP 1</td>
<td>240</td>
<td>256 200</td>
</tr>
<tr>
<td>Chun liang Liquor (CLYJ)</td>
<td>Cellulose 334, PET 3, PS 4, PU11, PA135, PVC 1, PP 20</td>
<td>496</td>
<td>538 490</td>
</tr>
<tr>
<td>Blank (Milli-Q water)</td>
<td>Cellulose 4</td>
<td>4</td>
<td>4 4</td>
</tr>
</tbody>
</table>

The most frequently found microplastics were cellulose (comprising 70.4% of the total) and PA (constituting 17.6% of the total). Other microplastic variants, namely PET, PP, PVC, and PE, were also identified, contributing 2.7%, 2.2%, 1.2%, and 0.1%, respectively. In contrast, only a small quantity of microplastics was discovered in the control groups (blank sample).

Several studies [19,20] indicate that synthetic textiles are the primary source of microplastics in the air, with fibers being the primary form in the atmosphere. The data show that 29% of these fibers consist of synthetic material. As a result of their low density, microplastics accumulate in the atmosphere and are transported globally, causing harmful health effects through inhalation or ingestion. Given the significant quantities of cellulose and PA detected, it is reasonable to assume that they originate from atmospheric deposition during the production, storage, and transportation of Chinese baijiu sold in plastic bottles. This study ensured strict control of air quality during the experiments conducted. Nevertheless, even in a strictly controlled environment, eliminating air contamination is an arduous task.

### 3.2. Distribution of the Size and Shape of Microplastics

The analysis of size distribution demonstrated that microplastics, which were present in the plastic-bottled Chinese baijiu samples, had sizes ranging from 25 µm to 5 mm. The majority of them fell in the category of 50–300 µm. The instruments used to measure the size had a detection limit of 25 µm, and the filters employed had a mesh size of 0.4 µm. Microplastics were segregated into six size classes (25–50 µm, 50–100 µm, 100–300 µm, 300–500 µm, 500–1000 µm, and 1000–5000 µm) and differentiated into two types: fibers and fragments.

Figure 4 illustrates the distribution of microplastics in RedStar Erguotou Liquor by length. The majority of these fibers consist of synthetic material. As a result of their low density, microplastics accumulate in the atmosphere and are transported globally, causing harmful health effects through inhalation or ingestion. Given the significant quantities of cellulose and PA detected, it is reasonable to assume that they originate from atmospheric deposition during the production, storage, and transportation of Chinese baijiu sold in plastic bottles. This study ensured strict control of air quality during the experiments conducted. Nevertheless, even in a strictly controlled environment, eliminating air contamination is an arduous task.

The analysis investigated the shapes of microplastic particles in the plastic-bottled Chinese baijiu samples. Figure 5 displays the distribution of microplastic shapes across the six brands of plastic-bottled liquors that were examined. The findings demonstrated that the types of microplastic particles differed among the various brands. Fibers were the most frequent type of microplastic particles identified, making up 88.2% of the total number of microplastic particles detected in Mao Pu pure grain wine. In Bu Lao Tan grain wine, the dominant microplastics were granules and fragments, making up 64% of all microplastic
particles. Notably, fibers accounted for 35.9% of the microplastics in Bu Lao Tan grain wine. In Hui Yi Erguotou Liquor, the microplastic particles were predominantly fibers and fragments, with fibers representing 51% and fragments accounting for the remaining 49% of the total microplastic particles. These findings suggest that the shapes of microplastic particles in plastic-bottled Chinese baijiu may differ depending on the brand, revealing the range of sources and types of microplastics present in the samples.

Figure 4. Microplastic size distribution in Chinese baijiu.

3.3. Validation and Data Analysis of Plastic-Bottled Chinese Baijiu Using Micro-FTIR

The FPA detector coupling allows for the entire filter area to be imaged, in contrast to single-point measurements. This method of analysis has the added advantage of collecting both spectral and spatial information of multiple particles simultaneously through automated mapping of a sample, enabling the analysis of small microplastics without the manual sorting and estimation of particles' characteristics such as their areas and diameters. The infrared spectrometer exhibits a superior spectral resolution of over 0.1 cm$^{-1}$ in the mid-infrared region and over 1 cm$^{-1}$ at a wavelength of 1000 nm in the near-infrared region. The equipment achieved a spatial resolution detection limit of 25 µm.

Statistical analysis was performed using MATLAB R2014a. This technique was pioneered by Jun-Li Xu in “Microplastic Characterisation by Infrared Spectroscopy”, found in the Handbook of Microplastics in the Environment, pp. 1–33, 2020 [21]. The authors provide an extensive account of the multiple approaches employed to analyze microplastics utilizing infrared spectroscopy. Specifically, the implementation of spectral imaging techniques along with spectral auto-analysis techniques can significantly enhance the efficacy of microplastic spectral analysis. MATLAB scripts and datasets are also provided in the book.
FTIR spectra of unknown species are typically identified by comparing their recorded spectra with those in a library of known substances. The Pearson correlation coefficient ($r$) is a method that has been suggested in determining the similarity between spectra [22]. To enhance the accuracy and robustness of library searching, a curve-fitting approach has been developed. This approach calculates a match by using the most relevant bands instead of the entire spectrum for identification [23–25]. By utilizing this robust identification method, MP identification accuracy can be increased from 60% to 98% compared to traditional library searching [26]. It is crucial to develop, validate, and improve automated analysis methods to reduce the identification time and enhance the accuracy and robustness of the complete analytical chain.

Taking the results of the Red Star Erguotou Liquor sample as a representative, Figure 6 displays the various types of plastic components, which are represented by the distinctive peaks observed in the micro-FTIR spectra. Using a Pearson correlation coefficient threshold of 0.7, our study identified the following five components in the plastic bottle of the Red Star Erguotou Liquor sample: cellulose, PET, PU, PA, and PVC, which were found at levels of 24, 72, 5, 16, and 1 microplastics, respectively.

The spectra’s characteristic peaks provided useful identification information. For instance, characteristic peaks for PA were given in Figure 7, whereby 1635 cm$^{-1}$ peaks correspond to carbonyl group absorption peaks ($\nu$ C=O). Furthermore, the 1537 cm$^{-1}$, 1264 cm$^{-1}$, and 1170 cm$^{-1}$ peaks correspond to vibration absorption peaks ($\nu$ C–N and $\nu$ C–O).

The spectra evidenced degradation of the plastic particles, attributable to alcoholic beverage exposure. This indicates that the environment can influence the chemical composition and structural integrity of microplastics present. In general, the micro-FTIR analysis provided valuable information about the chemical composition and potential degradation of microplastic particles in the Red Star Erguotou Liquor sample.
Figure 6. Microplastic abundance in the sample (quarter part).

<table>
<thead>
<tr>
<th>Sample</th>
<th>Cellulose</th>
<th>PET</th>
<th>PU</th>
<th>PA</th>
<th>PVC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red Star Erguotou Liquor (HX-1)</td>
<td>24</td>
<td>72</td>
<td>5</td>
<td>16</td>
<td>1</td>
</tr>
</tbody>
</table>

Figure 7. The FTIR spectra of typical microplastic particle samples within the range of 700–2000 cm$^{-1}$. 
4. Discussion

The occurrence of microplastics in Chinese baijiu samples can be traced back to various sources. Microplastics may be accidentally introduced during production and processing. Moreover, external or physical pressure on the bottles during handling, distribution, and utilization could lead to the discharge of microplastics from plastic packaging and bottle closures [27]. The elevated levels of microplastics detected in Chinese baijiu samples may arise from numerous origins, taking into account the extensive distribution of microplastics in the agricultural setting and throughout production processes. Microplastics may arise from polluted raw materials (e.g., water springs and grains), work attire, production settings, and the separation of plastic packaging materials.

Contamination of grains with microplastics can occur during their growth stage, as highlighted by previous studies [28]. Plastic mulch film, which is frequently employed in agriculture, has been identified as a possible origin of microplastic pollution in agricultural soils [29–31]. In 2022, Fuyuan Wang and colleagues discovered that rice seedlings are capable of accumulating nano- and microplastics in their roots, which can then be transferred to aerial tissues [32]. This indicates the possible transmission of amassed microplastics up the food chain to higher trophic levels. Water, an indispensable resource for wine production and cleaning, can also contribute considerably to the microplastic content in wine. In addition to water sources and plastic packaging being tainted with microplastics, the likelihood of their incorporation during the filling and sealing of wine bottles is feasible. During the production process, wines can come into contact with air, creating the possibility of airborne microplastic contamination. As such, it is possible that microplastic pollution in plastic-bottled Chinese baijiu originates from microplastic particles introduced during the brewing process of grains. Additionally, the physical stress applied to bottle caps during the decapping process could also contribute to contamination [33].

The existence of microplastics in alcoholic drinks gives rise to worries about likely health hazards, though the exact ramifications are yet to be comprehensively grasped. To appraise the consumption of microplastics through alcohol ingestion, a fusion of empirical data from six brands of alcohol packaged in plastic were utilized. This enabled us to compute the estimated annual intake (EAI) of microplastics.

Based on alcohol consumption data in China, the average per capita consumption of pure alcohol per year for residents over the age of 15 is 6.7 L. This corresponds to 12.88 L of common 52% alcohol content. An estimated annual intake of microplastics from drinking liquor is 11,231 MPs per year.

Although the impact of microplastic exposure on human health via food and drink has not been extensively researched, experimental animal studies suggest potential adverse effects. Inflammatory responses, gut microbial dysbiosis, impaired hepatic lipid metabolism, and dysfunction of the intestinal barrier [34–36] have all been linked to exposure to microplastics. Moreover, human tissues can absorb microplastics, where microplastics can induce oxidative stress [37], hinder the immune system [38], and serve as a vector for environmental contaminants [39–43]; the latter may increase toxic repercussions.

To evaluate and handle the hazards related to microplastics found in plastic-bottled baijiu sold in China, it is necessary to locate the origins of microplastics and create policies to limit their spread into the environment. Implementing strict control and reducing the likelihood of external pollution during processing can help to lower the level of microplastics in processed food ingredients and minimize the chemical risk and pollution load linked with microplastics present in plastic-bottled baijiu. Further research is required to gain a better comprehension of the health impacts of microplastics in food and drinks and to address the current gaps in knowledge.

5. Conclusions

In conclusion, this study employed micro-Fourier transform infrared microscopy to quantify microplastics in Chinese baijiu and evaluated their content using the Pearson correlation coefficient. The results verified the occurrence of microplastics in Chinese baijiu
stored in plastic bottles, which could pose a possible threat to public health. Cellulose and PA were the frequently found microplastic types. The mean concentration found was 436 particles/500 mL, with a range spanning from 172 to 944 particles/500 mL. Possible contamination sources encompass raw materials, the atmosphere, and equipment or containers releasing microplastics.

In contrast to reports on bottled water, microplastic concentrations observed in this analysis appear to be lower; however, comprehensive adverse health outcomes linked to microplastics in food and beverages are yet to be fully determined. Further research is required to provide essential information for consumers, regulators, and the food industry, facilitating a more comprehensive comprehension of the sources and potential impacts of microplastics in food and beverages. To tackle the risks posed by microplastics, we would like to conduct additional cellular experiments to investigate the impact of these minuscule plastic particles on human health. Furthermore, endeavors should be made to devise tactics that curtail the release of microplastics into the environment and guarantee the safety of the food supply chain.

Author Contributions: X.Z.: Conceptualization, Investigation, Data curation, Original draft preparation. J.W.: Reviewing and Editing. H.L.: Methodology, Formal analysis, Investigation. Q.W.: Data curation. J.R. and S.T.: Resources. All authors have read and agreed to the published version of the manuscript.

Funding: This research has been supported by the Zhejiang Market Regulatory Administration Science and Technology Program (Grant number: 20190101, ZC2021A015).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

Abbreviations

Microplastics (MPs); Fourier transform infrared spectroscopy (FTIR); Polyamide (PA); Polyethylene terephthalate (PET); Polypropylene (PP); Polyvinyl chloride (PVC); Polyethylene (PE); European Food Safety Authority (EFSA); Focal plane array (FPA); Polyurethane (PU); Polystyrene (PS).

References


40. Godoy, V.; Blázquez, G.; Calero, M.; Quesada, L.; Martín-Lara, M.A. The potential of microplastics as carriers of metals. Environ. Pollut. 2019, 255, 113363. [CrossRef]


Disclaimer/Publisher’s Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.