Application Note

Food and beverages

Microplastics Characterization in Carbonated Beverages and Apple Juice by Laser Direct Infrared

A rapid and automated approach using an Agilent 8700 LDIR chemical imaging system

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Abstract

Microplastics have become an unwelcome ingredient in food and drink, raising concerns about how plastic materials contribute to contamination. This study demonstrates a rapid, automated approach for detecting and characterizing microplastics in carbonated beverages and apple juice using an Agilent 8700 Laser Direct Infrared (LDIR) chemical imaging system. Samples packaged in various materials such as plastic, glass, aluminum cans, and multilayer cartons were analyzed directly on aluminum-coated filters, a process requiring minimal sample preparation. Using the Particle Analysis method and inbuilt microplastics spectral library within the Agilent Clarity software, microplastics were detected in all beverage types. Polyvinyl chloride (PVC) and polyethylene terephthalate (PET) were identified as the most prevalent polymers. The workflow, including robust quality control and direct-on-filter analysis, highlights the suitability of the 8700 LDIR for microplastics monitoring in food and beverage applications.

Introduction

The widespread use of plastic materials in the production, packaging, and distribution of foods and beverages has raised growing concerns about microplastic contamination. Popular beverages bottled in plastic-containing packaging are increasingly recognized as potential contributors to dietary microplastic exposure. Studies have reported microplastic particles in commercial mineral water and soft drinks, often introduced through bottling operations, cap abrasion, or migration from plastic containers and multilayer packaging materials.[1-4]

Carbonated beverages and apple juice are commonly packaged in a variety of container types, including polyethylene terephthalate (PET), polyethylene (PE), aluminum cans, glass bottles, and multilayer cartons. Microplastics may shed into the product from the packaging materials or be generated during the preparation and filling stages. Factors like high-speed bottling, carbonation pressure, and storage conditions can further accelerate the release of microplastics into the liquid matrix.[2,5]

Detecting microplastics in complex beverage formulations presents significant analytical challenges, primarily due to the presence of organic matter and mineral constituents in these products. Traditional techniques such as micro-Fourier Transform Infrared spectroscopy (μFTIR) and μRaman spectroscopy can effectively identify and characterize microplastics in beverages, typically following digestion and density separation to avoid matrix-related interferences. Also, method development and sample run times for both techniques are often labor-intensive and low-throughput, limiting the number of samples that can be processed within a given timeframe.

To address these limitations, the highly automated Agilent 8700 Laser Direct Infrared (LDIR) chemical imaging system (Figure 1) significantly improves sample throughput, enabling the rapid, accurate detection of microplastics in complex matrices following direct filtration. The system uses a Quantum Cascade Laser (QCL) that allows rapid and precise scanning across the mid-infrared (MIR) fingerprint region (1,800 to 975 cm^{-1}), providing high-quality spectral data. It also provides high-quality imaging data using two high-quality visual cameras that are fully controlled by the Agilent Clarity software. The software also includes preset methods such as Particle Analysis to simplify the analysis, as well as data reporting tools to aid interpretation and decision-making.

Figure 1. The Agilent 8700 LDIR chemical imaging system enables the high-speed routine analysis of microplastics, providing data on the number of particles present, size distribution, and chemical composition.

This application note demonstrates the use of the 8700 LDIR for the characterization of microplastics extracted from commercially available carbonated beverages and apple juice packaged in various container types. The particles were analyzed directly on aluminum-coated filters.

Experimental

Quality control

To ensure that any detected microplastics originated solely from the beverage samples, quality control (QC) procedures were applied to all reagents used in the analysis. All glassware, equipment, and tools were thoroughly cleaned with filtered ultrapure (microplastic-free) water and covered with aluminum foil before use to prevent environmental contamination.

For each sample, a procedural blank (45 mL of microplastic-free water) was prepared and analyzed under identical conditions—same operator, equipment, environment, and timings—as the test samples (Figure 2). This volume was selected to match the rinse volume used during sample preparation, as detailed in the sample preparation section.

Figure 2. The Agilent 8700 LDIR filter holder features two positions for sequential measurement of the blank and sample, enabling robust QC in microplastics analysis. The blanks and beverages were vacuum-filtered through aluminum-coated polyester membranes, which were then mounted onto the LDIR filter holder.

Sample preparation

Carbonated beverages: Three commercially available carbonated beverages, each of the same type but packaged in different containers (aluminum can, glass bottle, and recycled PET bottle (rPET)) were bought from a supermarket in Melbourne, Australia. To remove the dissolved carbon dioxide and prevent bubble formation during filtration, the beverages were degassed by opening the containers, loosely resealing them, and leaving for eight hours at room temperature. This time period allowed the gas to escape gradually while minimizing the risk of airborne contamination.

Following degassing, the entire volume of each beverage (see Table 2 for details) was vacuum-filtered through an aluminum-coated polyester membrane (25 mm diameter, 100/0 nm coating, 0.8 µm pore size, part number M7300-68011). To ensure complete recovery of any microplastic particles, the interior surfaces of the containers and filtration funnel were rinsed with 45 mL of microplastic-free water, which was then filtered through the same membrane.

After filtration, each membrane was carefully removed using clean tweezers and mounted onto a LDIR filter holder. The gold ring was gently tightened to secure the filter and ensure a flat, uniform surface for optimal imaging, as shown in Figure 2.

Apple juice: Two apple juice products, both reconstituted from juice concentrate and packaged in different containers (a plastic bottle and a multilayer carton), were also bought in the supermarket. However, direct filtration of the juice sample through an aluminum-coated polyester membrane (0.8 µm pore size) resulted in rapid clogging after approximately 100 mL had been filtered, due to the presence of subvisible particulates in the product.

To overcome this limitation, a two-step filtration protocol was implemented. First, the entire volume of each apple juice sample was prefiltered using a 47 mm polycarbonate membrane with a 5 µm pore size, allowing efficient processing without filter blockage. After drying, the polycarbonate filter, which was carefully handled with clean tweezers, was rinsed with 45 mL of microplastic-free water to transfer the retained particles.

This rinse was then filtered through an aluminum-coated polyester membrane (25 mm diameter, 100/0 nm coating, 0.8 µm pore size). The final membrane was dried at room temperature for ~2 minutes and mounted onto the filter holder, ready for analysis.

Instrumentation

The 8700 LDIR system's fully automated particle analysis workflow was used in this study. The aluminum-coated filters loaded with microplastic particles from each sample, as well as the blanks, were analyzed by the LDIR using the fully automated Particle Analysis method in the Clarity software. The method setup parameters used for data acquisition are shown in Table 1. Instrument and method parameters were set to the instrument default settings, simplifying the analysis.

Table 1. Agilent 8700 LDIR chemical imaging system operating parameters used for the automated analysis of microplastics in various beverages.

Parameter	Setting
Method	Particle Analysis
Library Used	Microplastics Starter 2.1[6,7]
Auto Scan	On
Collect Visible Images	Yes
Particle Sensitivity	Automatic
Hit Quality Index Ranges	Hit quality describes how closely the spectrum of the sample matches that in the reference library. For this experiment, classification ranges (i.e., the characterization of spectral match quality by high, medium, and low) were set to: – Low confidence (0.65 to 0.75) – Medium confidence (0.75 to 0.85) – High confidence (0.85 to 0.99) Any particles falling outside this range (i.e., < 0.65) were classified as "undefined"
Size Classification Range (µm)	20 to 50 50 to 100 100 to 500 > 500

Results and discussion

Reporting

For reporting of the microplastic data, all non-microplastic particles were excluded (for example, natural polyamide, stearates, cellulosic materials, carbonates, etc.). All other major microplastic types were reported based on selected hit quality index (HQI) criteria of > 0.85. The microplastics included: acrylonitrile butadiene styrene (ABS), polyamide (PA), polycarbonate (PC), polyethylene (PE), polyethylene terephthalate (PET), polyoxymethylene (POM), polytetrafluoroethylene (PTFE), polypropylene (PP), polystyrene (PS), polyurethane (PU), and polyvinyl chloride (PVC).

Quality control

To ensure the reliability of microplastics analysis, established methodologies (for example, ISO/DIS 16094-2, EU Regulation 2024/1441, and the California Water Boards protocol) recommend the inclusion of procedural blanks to monitor potential contamination from equipment, reagents, and the laboratory environment. In this study, five procedural blanks were analyzed, yielding a mean background level of two microplastic particles per 45 mL ($\mu = 2$) with a standard deviation of 1.4 particles ($\sigma = 1.4$), providing a baseline for interpreting the sample results.

Carbonated beverages

To locate particles and define their boundaries, the 8700 LDIR automated Particle Analysis workflow conducted an initial rapid scan over a selected area (~16 mm diameter per filter) using a fixed wavenumber (1,442 cm^{-1}). Following detection, the system automatically acquired full infrared spectra for each particle across the spectral range. These spectra were then matched in real time against the Microplastics Starter 2.1 spectral library for identification.

Although a residue layer was observed on the aluminum-coated filters following filtration of the carbonated beverages, it did not interfere with the LDIR's particle detection or identification capabilities (Figure 3). As shown in Table 2, microplastics were identified in all three beverage samples, with particle counts of 50, 39, and 384 for samples 1, 2, and 3, respectively (HQI > 0.85).

PVC was detected across all container types, such as rPET (37 particles), aluminum can (25 particles), and glass, which unexpectedly exhibited the highest particle count (227 particles). This may be attributed to the cap liner material (often a multilayer seal designed to prevent oxygen or moisture ingress) or potential cross-contamination during bottling through piping systems. PET microplastics were also identified in all samples, with particle sizes ranging from 20 to 500 µm (Table 2).

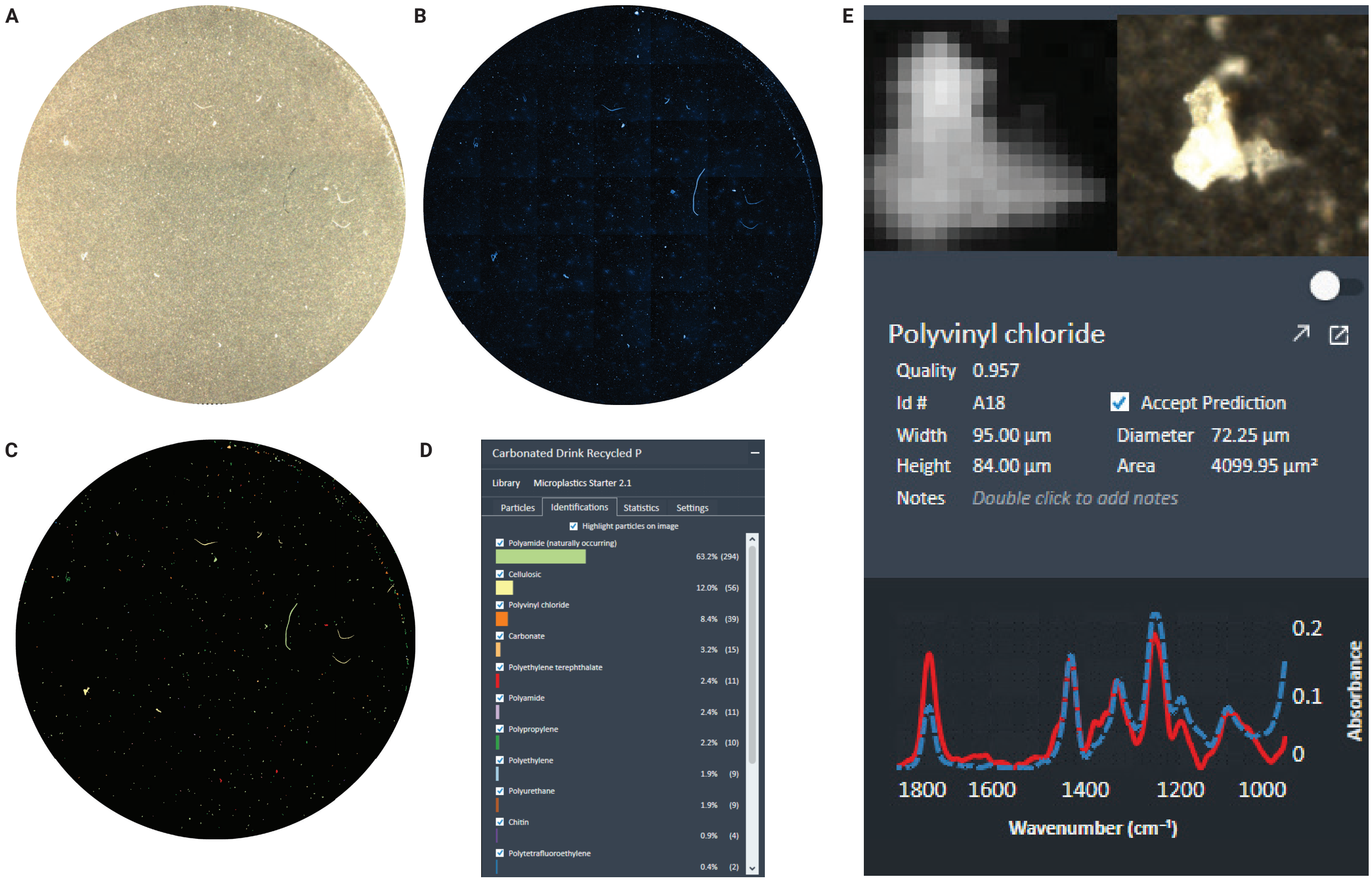


Figure 3. Identification and classification data of microplastics in an rPET bottled carbonated beverage analyzed directly on aluminum-coated membrane filter using the Agilent 8700 LDIR system's automated Particle Analysis workflow. (A) Visible image of the filter. (B) IR image scanned at 1,442 cm^{-1}. (C) Highlights of particles found—the color of the particles relates to the type of microplastic on the filter. (D) Automatically generated statistical data based on the identification of microplastics in the sample. (E) Example of PVC microplastic spectrum (solid red line) identified in the sample by matching to the library spectrum (dashed blue line).

Apple juice

The 8700 LDIR Particle Analysis workflow was also used to analyze the apple juice samples, scanning an area of approximately 16 mm. As the samples were prefiltered using 5 µm polycarbonate filters, no visible juice residue was observed on the final aluminum-coated filters. Most detected particles were attributed to undigested juice constituents, including naturally occurring polyamides and cellulosic materials. However, microplastics were also identified.

In the apple juice packaged in a carton, 66 microplastic particles were detected in the 200 mL sample, with an HQI greater than 0.85. The predominant polymer identified was polyethylene (54 particles), likely originating from the inner polyethylene layer of the carton's multilayer packaging structure. In comparison, the apple juice packaged in a PET plastic bottle contained 20 microplastic particles in 250 mL, with PET being the primary polymer detected (9 particles). Examples of microplastics from both samples are shown in Figure 4.

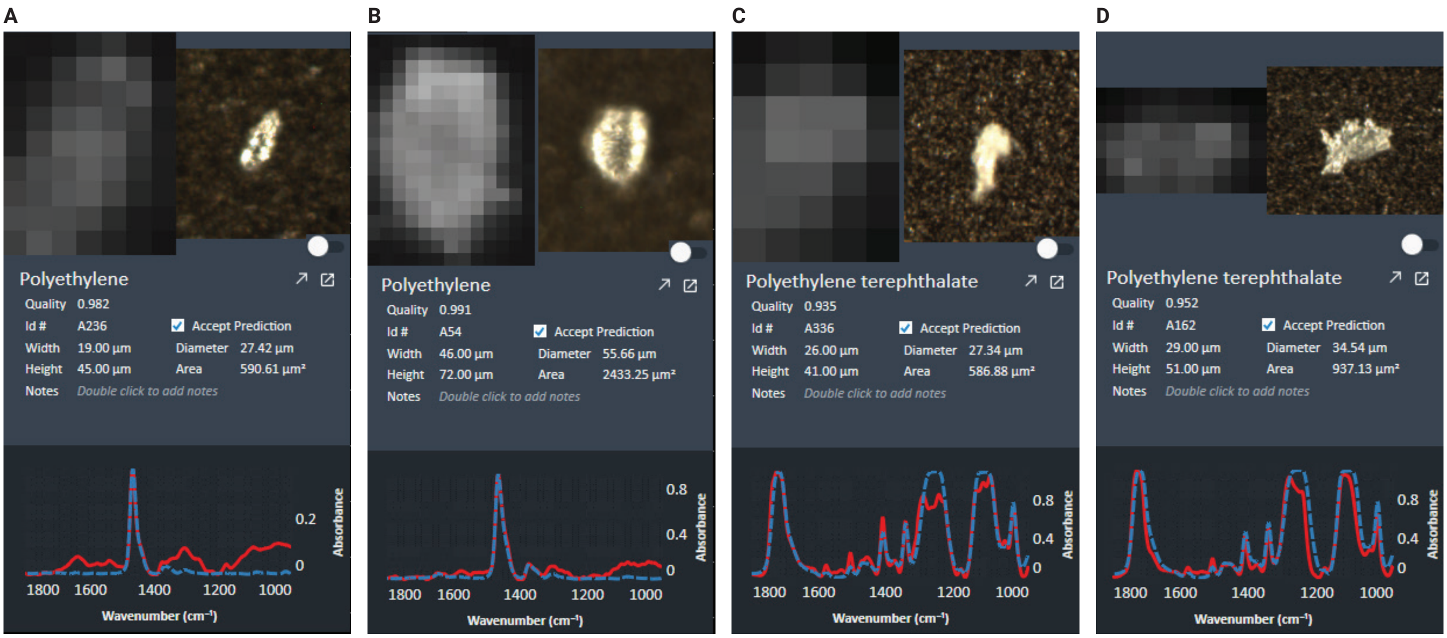
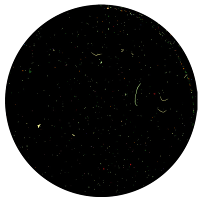
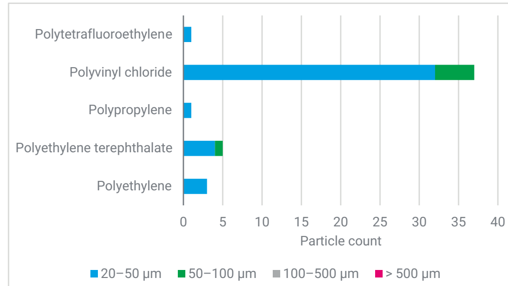
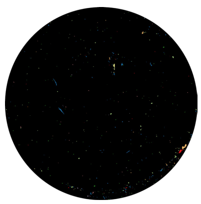
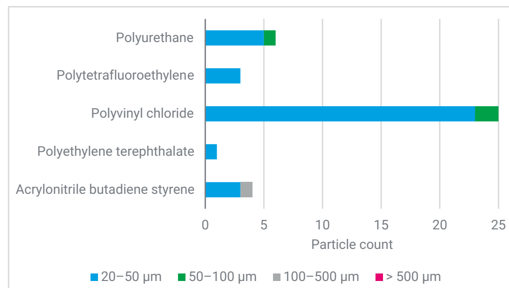
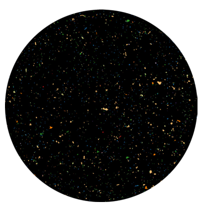
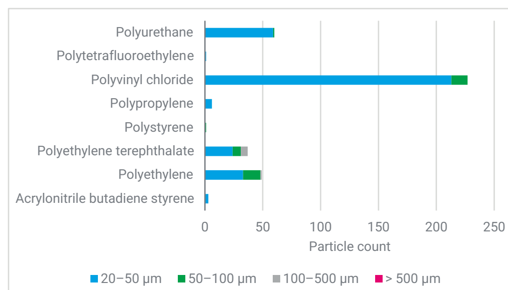
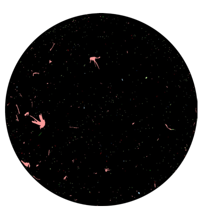
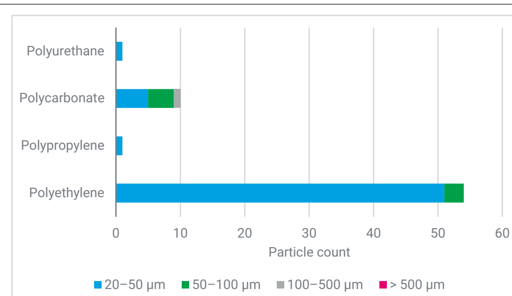
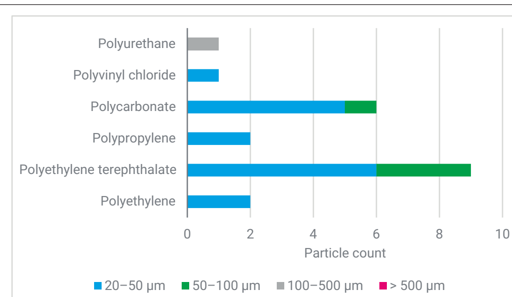


Figure 4. Examples of microplastics identified in apple juice samples: PE from the multilayer carton packaging (A and B) and PET from the plastic bottle packaging (C and D).

Table 2. Microplastic characterization result summary for carbonated beverages and apple juice samples.

Sample	Container Type and Volume	Highlights of Particles Detected	Total Number of Particles	Number of Microplastics with HQI > 0.85	Size Distribution and Identification of Microplastics
Carbonated Beverage 1	rPET (300 mL)		660	50	
Carbonated Beverage 2	Al Can (250 mL)		475	39	
Carbonated Beverage 3	Glass (330 mL)		2284	384	
Apple Juice 1	Carton (200 mL)		885	66	
Apple Juice 2	PET (250 mL)		590	21	

Conclusion

This study highlights the advantages of using the Agilent 8700 LDIR chemical imaging system for characterizing microplastics in carbonated beverages and apple juice contained in various types of packaging. When consumed, these drinks may serve as potential sources of microplastic exposure.

The 8700 LDIR enabled a direct on-filter analysis approach that significantly simplified the workflow by eliminating traditional preparation steps such as digestion and density separation, speeding up the analysis. The on-filter method reduced the potential for sample contamination while enhancing recovery rates and sample representativeness by enabling filtration of the entire product volume.

The two-position filter holder facilitated the automated, sequential analysis of both a procedural blank and sample under identical conditions, supporting an accurate quality control process.

The automated Particle Analysis method in the Agilent Clarity software was used to detect and process data from microplastics contained on the two filters. The software automatically searched the microplastics IR spectral library to identify the polymer type of each particle, providing a "Hit Quality Index" confidence rating for each result. Using this fast and automated workflow, the 8700 LDIR characterized the microplastic content of the beverages with minimal operator input.

The detailed chemical and physical information generated for each particle by the 8700 provides valuable insight into microplastic pollution, particularly in food and beverages. This data supports the identification of potential contamination sources and facilitates assessment of their broader environmental and human health impact of microplastics.

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Further information

– Agilent 8700 LDIR chemical imaging system
– Agilent Clarity Software
– Microplastics Technologies FAQs
– Microplastics Analysis in Water
– Microplastic Characterization in Infant Formula

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