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FROM ISOLATION TO DETECTION OF MICROPLASTICS IN NATURAL AND INDUSTRIALLY PROCESSED HONEY

Anja Bubik[1], Faculty of Environmental Protection, Trg mladosti 7, 3320 Velenje, Slovenia
Klara Hohkraut[2], Faculty of Environmental Protection, Trg mladosti 7, 3320 Velenje, Slovenia

Abstract: *Plastic pollution is a growing environmental concern, with microplastics increasingly found in natural ecosystems and food products. This study evaluates the presence of microplastics in honey and compares their occurrence in natural and industrially processed samples. Various sample preparation methods were tested, and the most effective—based on oxidation and filtration—was used to isolate and identify potential synthetic particles. The analysis using microscopy and FTIR spectroscopy confirmed the presence of microplastic-like particles in all six honey samples, with colored fibers detected in four of them. Natural linden honey exhibited the highest proportion of colored fibers (26.7%), while industrial linden honey showed a similar trend (24.0%), suggesting a consistent susceptibility of this honey type to fiber contamination. These findings highlight the influence of plant origin and environmental exposure on microplastic contamination in honey.*
Keywords: Microplastics, Honey contamination, Food safety, Filtration method, Environmental pollution

1. INTRODUCTION

Plastic pollution has emerged as one of the fastest-growing environmental problems of the 21st century, primarily due to the widespread production and use of plastic products, and limited recycling capacity. As plastic waste breaks down in the environment or when plastic materials wear down, rub against each other, or are simply used, small particles, called microplastics (MPs), typically defined as particles less than 5 mm in diameter, are released into the environment [e.g. 1, 2]. In recent years, MPs have been detected in virtually all ecosystems, from the deepest oceans to remote mountain regions. They have also been found in a wide range of food products and beverages, including beer, water, salt, and honey [3, 4]. This omnipresence is particularly concerning as MPs can enter various organisms, including the human body through ingestion and inhalation, posing potential health risks to both ecosystems and human health [5, 6, 7].
Honey contamination provides a specific example of how environmental pollution infiltrates natural food systems. Honeybees, through their active interaction with plants, air, soil, and water near the hive, are exposed to pollutants that can be transferred into their bodies and hive products [8]. While foraging for nectar, honeydew, pollen, water, and plant exudates such as propolis, bees encounter nearly all environmental compartments (Figure 1). Airborne MPs, originating from industrial zones, traffic emissions, and urban dust, pose a particular risk. According to the International Union for Conservation of Nature (IUCN), urban dust accounts for approximately 24% of MPs found in oceans, highlighting the magnitude of airborne contamination [9]. Once inside the hive, microplastic particles may persist through the natural honey-making process and end up in the final product. In addition to environmental exposure, plastic contamination may also occur during honey extraction, processing, filtration, or packaging [10]. Given their sensitivity and wide foraging range, honeybees are considered effective bioindicators for monitoring environmental quality [11,12,13]. The presence of

[1]anja.bubik@fvo.si
[2]klarahohkraut1@gmail.com

MPs in hive products raises important questions about honey's food safety and the broader implications of microplastics in the human diet.

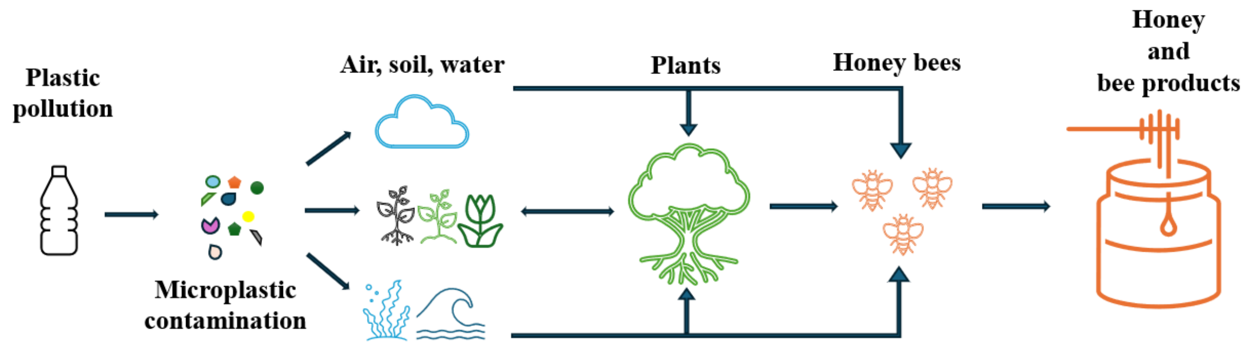

Figure 1. Flow of microplastic particles through the environment and their potential transfer into honeybees and hive products
Source: Bubik, 2025 (adapted from [10])

However, despite the growing recognition of this issue, research on MPs in honey remains limited. Most existing studies focus on aquatic organisms, while less attention has been given to terrestrial foods, such as honey, that are assumed to be less exposed. Furthermore, there is no standardized method for detecting or quantifying microplastics in honey, making comparisons between studies difficult and regulatory control almost impossible [14,15].
The aim of this study was to examine the presence of microplastics in different types of honey and to evaluate laboratory methods for sample preparation and particle detection. By comparing samples of natural and industrially processed honey across several types, this research contributes to a better understanding of microplastic contamination pathways and supports the call for more robust, standardized analytical methods.

2. MATERIALS AND METHODS

2.1 Sample Collection

This study analyzed six honey samples, acacia, floral, and linden, in both natural and industrially processed forms. The natural honey samples were of Slovenian origin, obtained directly from a local certified beekeeper to reflect minimally processed and regionally sourced products. The industrially processed honey samples represent widely available commercial products that are commonly used and sold across various stores in Slovenia. All samples were stored in sealed glass jars at room temperature prior to analysis. To minimize contamination, samples were handled using non-plastic laboratory tools, and all procedures were carried out in a clean, ventilated workspace.

2.2 Method Selection

The identification of microplastics in food products, particularly in complex matrices like honey, requires a reliable and selective method of sample preparation. Several studies have proposed and validated various approaches, including enzymatic digestion, chemical oxidation, and density separation as suitable pretreatment techniques for isolating synthetic polymers from organic-rich samples such as honey or seafood [16,17,18]. Following this established practice, we preliminarily tested multiple methods to evaluate their efficiency in breaking down the honey matrix, removing natural impurities, and preserving synthetic particles.

2.3 Microplastics Isolation and Identification

The method selected for the isolation of microplastics from honey was based on chemical oxidation using hydrogen peroxide (H_2O_2) followed by vacuum filtration, a technique widely used in recent microplastic research to effectively digest organic matrices while preserving synthetic particles [17,18]. The procedure began by mixing honey and distilled water in a 1:3 ratio and gently heating the solution to 40–45 °C to ensure complete dissolution and homogenization. We then added an equal volume of 30% H_2O_2 to the diluted sample and allowed it to react at room temperature for 24 hours, enabling oxidative breakdown of organic matter (Figure 2, left). After oxidation, we filtered the solution using a vacuum filtration setup with glass fiber filters (8 µm pore size), which had been pre-weighed and handled carefully to prevent contamination (Figure 2, right). The filters were left to dry at room temperature in a clean, closed glass container for at least 48 hours before we proceeded with microscopic analysis.

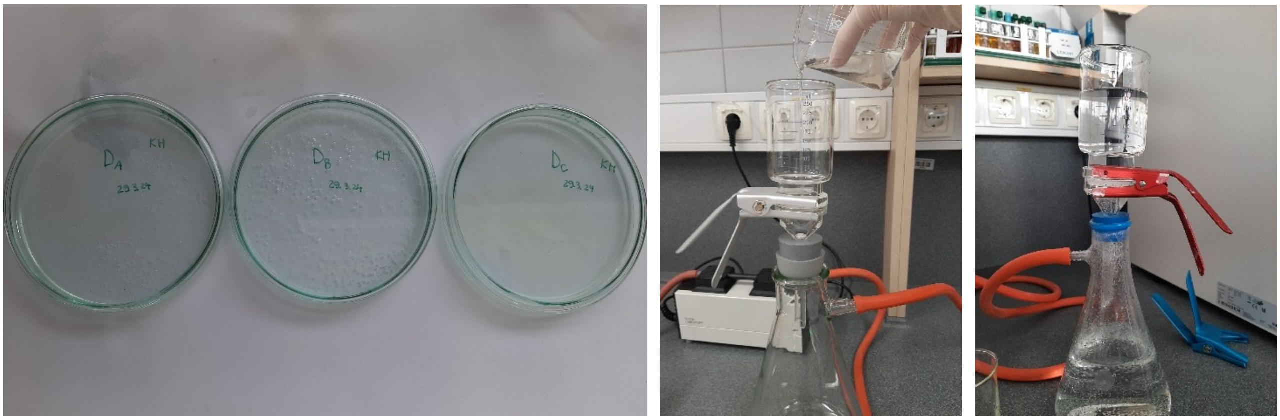

Figure 2. Chemical oxidation of honey samples with hydrogen peroxide (left) and vacuum filtration of oxidized solution using glass fiber filters (right)

Source: Hohkraut, 2024

This method effectively removed natural organic matter while preserving suspected microplastic particles, particularly synthetic fibers, on the filter surface. Dried filters were examined under a microscope, and potential plastic particles were extracted and identified using FTIR spectrometry.

3. RESULTS

The sample preparation method based on hydrogen peroxide oxidation followed by vacuum filtration was confirmed to be effective for isolating microplastic-like particles from honey. The method successfully removed organic matrix components without damaging the suspected synthetic particles, which remained visible on the glass fiber filters.

The analysis of six honey samples revealed the presence of potential microplastic particles in all samples, with colored, fiber-like particles detected in four of them. Table 1 summarizes the occurrence and distribution of microplastics in both natural and industrially processed honey. The total number of potential microplastics ranged from 36 in natural acacia honey to 56 in natural floral honey. Identified potential microplastic particles were categorized into two types—particles and fibers—with fibers further classified as either colored or uncolored.

In natural honeys, particles dominated acacia (83.3%), while fibers were more prevalent in floral (53.6%) and especially in linden honey (56.6%), which also exhibited the highest proportion of colored fibers (26.7%). Industrial honeys displayed comparable overall particle loads (45–57), but their composition varied. Acacia honey contained a nearly equal distribution of particles (47.4%) and fibers (52.6%), with 16.7% of the fibers being colored. Floral honey was strongly dominated by particles (86.7%), with minimal fiber content (13.3%) and no colored fibers detected. Linden honey exhibited the highest fiber proportion among industrial samples (55.6%), and also the highest share of colored fibers (24.0%).

Table 1. Summary of overall results from the analysis of natural and industrially processed honey
Source: Bubik & Hohkraut, 2025

Honey source	Honey type	Total No of potential microplastics	Particles (%)	Fibers (%)	Colored Fibers (%)
NATURAL	Acacia	36	83.3%	16.7%	/
	Floral	56	46.4%	53.6%	10.0%
	Linden	53	43.4%	56.6%	26.7%
INDUSTRIAL	Acacia	57	47.4%	52.6%	16.7%
	Floral	45	86.7%	13.3%	/
	Linden	45	44.4%	55.6%	24.0%

Linden honey had the highest proportion of colored fibers in both natural and industrial categories, suggesting a consistent pattern of increased susceptibility to this type of microplastic contamination. This type of honey may be particularly susceptible to microplastic fiber contamination due to several interrelated factors. Linden trees are commonly found in urban and roadside environments, where airborne microplastics, especially colored synthetic fibers from textiles and traffic, are more prevalent. The floral structure of linden blossoms, which bloom in dense clusters and attract bees for prolonged foraging, also increases the likelihood of microplastic deposition and transfer [19]. Additionally, hive management practices, such as the use of synthetic microfiber sheets to trap pests, can introduce additional fibers into the hive, which bees may fragment and incorporate into honey [20]. The physical properties of linden honey, including its lighter color and lower viscosity, may further facilitate the retention and visibility of microplastic fibers [21]. Last but not least, synthetic textile microfibers are recognized as a major environmental concern, representing the largest share of primary microplastics released globally into the oceans [9].
Microscopic images of the filters showed visually distinguishable fibers and some particles (e.g. yellow and green, Figure 4a and b, respectively) against the clean filter background. The most striking results were recorded for the natural linden honey sample, where multiple red, blue, and black fibers were observed (Figure 4c and d).

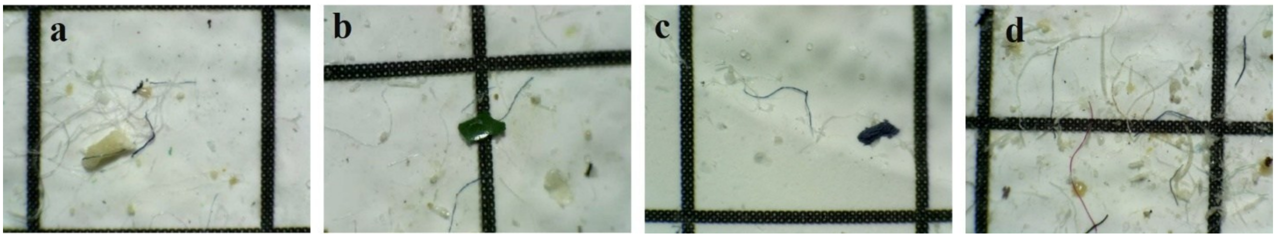

Figure 4. Colorful fibers detected in examination of filter papers.
Source: Hohkraut, 2024

Due to the small size of the fibers and fragility of some detected particles, FTIR spectroscopy did not provide conclusive identification of polymer types. Nevertheless, the visual characteristics under stereomicroscopy were consistent with microplastic fibers described in existing literature [e.g. 22,23]. Although none of the particles analyzed in this stage were suitable for precise polymer confirmation, further analysis using micro-FTIR (µFTIR) is planned, with a specific focus on fibrous particles, to provide more accurate chemical characterization. These results demonstrate that both natural and industrial honey types are consistently contaminated with MCs, though the relative proportions of particles, fibers, and colored fibers vary by botanical origin. The variation between honey types and production methods suggests that environmental exposure and processing techniques both contribute to contamination. These findings are consistent with other studies reporting airborne sources of microplastics, including urban dust and textile fibers, as potential routes of entry into beehives and final food products [9,24,25].

4. CONCLUSION

This study confirmed that honey can be contaminated with fiber-like particles consistent with MPs, and that their occurrence varies depending on the type of honey and its method of production. Natural linden honey showed the highest number of suspected microplastic fibers, likely due to environmental exposure in the foraging zones of bees. Processed acacia honey also showed contamination, which supports the hypothesis that synthetic particles may be introduced not only from the environment but also during mechanical processing steps such as filtration, bottling, or packaging. The oxidation-filtration method proved to be reliable for isolating potential microplastics in honey, particularly due to its simplicity and low cost. However, limitations remain in the ability to identify particle composition with FTIR spectrometry, especially when particles are small, thin, or embedded in filter fibers.

Given the rising awareness of microplastic exposure in food systems, the results of this study contribute to a growing body of evidence that MPs are not confined to aquatic products but are also present in terrestrial, natural foods such as honey. Further investigations should focus on broader sampling, improved polymer identification, and risk assessment for human health. Regulatory attention will also be required to establish thresholds, quality control measures, and labelling standards for microplastic content in food products.

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