REVIEW PAPER

Microplastics in Food Products: An Overview of Current Research

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Abstract

The extensive use of plastic materials throughout the food supply chain has led to a growing concern regarding the occurrence of microplastics and nanoplastics in foods and beverages. Due to their resistence to degradation and lifespan, plastics gradually fragment into smaller particles that can disperse through water, soli and air, eventually reaching food products. This paper examines the current state of knowledge regarding the occurrence of microplastics in food products and beverages. Particular attention is given to the contamination pathways and the role of food-contact materials, as a potential sources of plastic particles. Microplastics have been detected in drinking water, bottled water, milk, alcoholic and non-alcoholic beverages, salt, honey, vegetables, meat and processed meat products. Polyethylene, polypropylene and polyethylene terephthalate were among the most commonly reported polymers. Besides packaging materials, contamination arises from the environmental exposure, feed, water, food processing equipment and plastic cutting boards. However, substantial methodological inconsistencies among studies continue to hinder robust comparisons and accurate assessment of contamination levels. Future research should prioritize the development of standardized analytical methods, the identification of major contamination pathways, and the development of effective strategies to reduce plastic consumption and improve plastic waste management across the food supply chain.

Keywords: microplastics, food contamination, food packaging, food safety

Introduction

Plastics represents an integral component of modern society and are extensively used in numerous industrial sectors due to their favourable mechanical characteristics, high durability and relatively low production costs (Kannan & Vimalkumar, 2021). As a result, global plastic production has grown dramatically, rising from approximately 2 million tonnes in the 1950s to more than 450 million tonnes today (Our World In Data, 2026). Notably, over 50% of total historical plastic production has occurred since 2000, yet recycling rates remain low, reaching only about 9 % (European Environment Agency, 2024). According to OECD (2022), nearly half of all plastic waste is disposed of in sanitary landfills, whereas a substantial proportion continues to be managed through uncontrolled disposal pathways including open burning, uncontrolled dumping and direct release into the environment. Such practices facilitate the long-term accumulation and fragmentation of plastic materials, ultimately leading to the formation of microplastics and nanoplastics

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in environmental and food matrices.

The consequences of inadequate plastic waste management are particularly evident in marine ecosystems, where plastic debris is transported and concentrated by large-scale ocean circulation systems. One of the most striking examples is the Great Pacific Garbage Patch (Lebreton et al. 2018, 2024; Domenech & Marcos, 2021), informally described as the "seventh continent". Toussaint et al. (2019) reported that this accumulation zone expands over more than 1,6 million km^2 and is estimated to contain about 79 thousand tonnes of floating plastic material, which is an area exceeding three times the size of Spain. Although larger plastic items contribute substantially to the total mass, microplastic particles dominate numerically, representing around 94 % of all plastic pieces detected within the patch. The environmental dissemination of microplastics extends beyond ecological concerns, as these particles can ultimately reach consumers through contaminated food and drinking water. The detection of microplastics in human biological samples, such as stool, blood and placenta (Habib et al. 2022a; Čapla et al. 2026), highlights the need for further investigation of dietary exposure pathways.

The aim of this paper is to summarize current knowledge on the occurrence of microplastics in food and beverages, with particular attention to meat and meat products.

Definition, classification and characteristics of micro – and – nanoplastics

From a chemical perspective, plastics consist predominantly of long-chain polymeric structures characterized by high molecular weight. Their durability, lightness, versatility and insulating capacity have contributed to their global proliferation. However, once plastic debris enters the environment, it is subjected to multiple degradation pathways, including photochemical oxidation, mechanical abrasion and biologically mediated alteration. Through these weathering mechanisms, larger plastic items are gradually broken down into smaller fragments, commonly referred to as microplastics and nanoplastics (Liu et al. 2021).

Microplastics (MPs) and nanoplastics (NPs) are distinguished according to the particle size, whereas MPs are generally defined as plastic particles ranging from 1 µm to 5 mm, and NPs as particles ranging from 1 nm to 1 µm (Toussaint et al. 2019; Cverenkárová et al. 2021; Domenech & Marcos, 2021; Liu et al. 2021; Habib et al. 2022a; Bristi & Islam, 2026). However, there is no complete consensus regarding the precise lower limit of MPs or the upper limit of NPs, leading to differences in terminology and analytical approaches. Although definitions vary, the 5 mm cut-off remains widely adopted for MPs because smaller particles show distinct environmental persistence, mobility and biological availability (Domenech & Marcos, 2021; Jin et al. 2021; Bristi & Islam, 2026). Based on their origin, MPs are classified as either primary or secondary (Cverenkárová et al. 2021). Primary MPs are designed and manufactured as small polymer particles for specific technological or consumer applications, such as industrial pellets, abrasive particles, microbeads or synthetic fibers. In contrast, secondary MPs originate from larger plastic materials after their release into the environment, due to the previously mentioned influence of physicochemical and biological mechanisms (Cverenkárová et al. 2021; Bristi & Islam, 2026).

In addition to size and chemical composition, MPs are characterized by their physical properties, particularly shape and color. Based on their morphology, MPs can be classified into five principal categories: fibers, fragments, films, foams, and microbeads. Fibers are thread-like particles that predominantly originate from synthetic textiles, fishing nets, and other filamentous plastic materials. The mechanical breakdown of larger plastic objects, such as bottles, can generate rigid fragments characterized by irregular or angular shapes. In contrast, films are thin and flexible particles commonly associated with the fragmentation of plastic bags, packaging films, and wrapping materials. The degradation of expanded polystyrene and other foamed plastic products can generate lightweight, porous particles, commonly referred to as foams. Unlike these secondary particles, microbeads are generally spherical and intentionally manufactured for use in certain personal care products and industrial applications (Fox et al., 2024).

Another relevant characteristic of microplastics is their color, which may provide additional information on particle properties and potential origins. According to Pfaff (2021), plastic

colorants are classified into pigments (insoluble and dispersed within the polymer matrix), and dyes (soluble in the polymeric material). Pigments are further categorized as inorganic or organic. A wide range of white, yellow, red, brown, black, and green shades can be achieved through the incorporation of inorganic pigments, including titanium dioxide, zinc compounds, iron oxides, and chromium oxide. In contrast, organic pigments, such as azo, diarylide, and phthalocyanine pigments, are commonly employed to obtain yellow, orange, red, and blue tones. Fluorescent pigments and dyes produce bright, intense colors, whereas metal-complex dyes are used to obtain specific shades. It should be emphasized, however, that color alone does not allow reliable identification of the polymer composition or origin of microplastic particles. Therefore, color represents an additional characterization parameter that should be considered together with particle morphology and chemical composition (Pfaff, 2020; Fox et al., 2024).

The identification and quantification of microplastics in food products and beverages require appropriate sample preparation and particle extraction, prior to physical and chemical characterization. Depending on matrix complexity, chemical or enzymatic digestion is used to remove organic matter, followed by filtration, density separation, or centrifugation to recover plastic particles. Among the available analytical techniques, optical microscopy, Fourier-transform infrared (FTIR) spectroscopy, and Raman spectroscopy are the most commonly employed methods for microplastic characterization in food and beverage matrices. Optical microscopy is primarily used to assess particle abundance, size, shape, and color, whereas FTIR and Raman spectroscopy enable the identification of polymer composition. Complementary information on polymer identity and mass concentration can be provided using mass spectrometry-based techniques, depending on the analytical approach. However, differences in sample preparation, analytical sensitivity, particle-size detection limits, and reporting units continue to limit the comparability of results across studies. Therefore, establishing standardized analytical methods remains a key priority for improving the reliability, reproducibility, and comparability of microplastic detection and quantification in food products (Bhattacharya et al., 2026).

The persistence of plastic materials in the environment intensifies their long-term ecological impact, as many polymers degrade extremely slowly under natural conditions. For example, Kannan and Vimalkumar (2021) reported that polyethylene terephthalate (PET) water bottles may remain in the environment for approximately 450 years, disposable diapers for about 500 years, while polystyrene (PS) foam can persist for more than 5,000 years. Such extended degradation periods enable continuous weathering and fragmentation of plastic debris, increasing the formation of secondary MPs. As these particles disperse through soil, water and atmospheric pathways, they may ultimately contaminate food products and beverages intended for human consumption (Toussaint et al. 2019).

Most frequently applied plastic polymers in the food production and packaging

A wide range of synthetic polymers is currently employed in food production, processing and packaging systems. Among them, polyethylene (PE), polypropylene (PP), polyethylene terephthalate (PET), polystyrene (PS), polyvinyl chloride (PVC), polycarbonate (PC) and polyurethane (PU) dominate (Cverenkárová et al. 2021; Liu et al. 2021; Kannan & Vimalkumar 2021; Agriculture Institute, 2025) because of their mechanical strength, chemical resistance, transparency, flexibility and suitability for direct food-contact materials. Table 1. provides an overview of the principal plastic polymers used in the food industry and their typical applications.

It can be observed that PET, PP and HDPE are extensively used in the production of beverage bottles, dairy packaging, food containers, edible oil packaging and condiment bottles (Liu et al. 2021; Agriculture Institute 2025; Thangamuniyandi et al. 2025). In contrast, PS (Ojha & Maurya 2023), and PVC (Thangamuniyandi et al. 2025) are associated with disposable food-contact materials, including trays, films, lids and takeaway packaging. Hence, LDPE is utilized in flexible packaging (eg. shopping bags, bread bags and frozen food packaging) (Agriculture Institute, 2025; Thangamuniyandi et al., 2025). Given the extensive use of synthetic polymers in food-contact products, it is not surprising that growing scientific attention has been directed towards the occurrence, concentration and polymeric composition of MPs in foods and beverages.

Table 1 Overview of the most commonly used polymeric (plastic) materials used in food packaging and processing.
Tablica 1. Pregled najčešće korištenih sintetskih polimera (plastike) u prehrambenoj ambalaži i preradi hrane.

Polymer / Polimer	Abbreviation / Kratica	Application in the Food Industry / Primjena u prehrambenoj industriji	Reference / Referenca
Polypropylene / Polipropilen	PP	Drinking and milk bottles, food containers, yogurt cups, sour cream and cream cheese containers, syrup packets, and lids for condiment bottles / boce za piće i mlijeko, spremnici za hranu, čašice za jogurt, posudice za kiselo vrhnje i krem sir, vrećice za sirupe te čepovi i poklopci za boce s umacima i začinima	Liu et al. (2021); Ojha & Maurya (2023); Agriculture Institute (2025); Thangamuniyandi et al. (2025)
Polyvinyl chloride / Polivinil-klorid	PVC	Plastic bags, stretch films for frozen foods, and container lids / plastične vrećice, strech folije za smrznutu hranu, poklopci za spremnike i posude za hranu	Thangamuniyandi et al. (2025)
Polyethylene terephthalate / Polietilen - tereftalat	PET	Water, juice and soft drink bottles, food containers, microwavable containers, plastic films, packaging for oils, condiments and dressings, trays for bakery products / boce za vodu, sokove i bezalkoholna pića, spremnici za hranu, posude za mikrovalnu pećnicu, plastične folije, ambalaža za ulja, umake i preljeve te pladnjevi za pekarske proizvode	Liu et al. (2021); Agriculture Institute (2025); Thangamuniyandi et al. (2025)
Polystyrene / Polistiren	PS	Disposable food and beverage packaging, meat trays, egg cartons, takeaway containers, straws / jednokratna ambalaža za hranu i napitke, pladnjevi za meso, kutije za jaja, ambalaža za hranu za van, slamke.	Ojha & Maurya (2023); Agriculture Institute (2025); Thangamuniyandi et al. (2025)
Low-Density Polyethylene / Polietilen niske gustoće	LDPE	Shopping and bread bags, frozen food packaging, disposable food-service items / vrećice za kupovinu i kruh, ambalaža za smrznutu hranu, jednokratni pribor za posluživanje jela	Agriculture Institute (2025); Thangamuniyandi et al. (2025)
High-Density Polyethylene	HDPE	Water, milk, juice and syrup bottles, grocery bags, grocery bags and packaging liners for cereals and snacks / boce za vodum, mlijeko, sokove i sirupe te unutarnje obloge za ambalažu žitarica i grickalica	Agriculture Institute (2025); Thangamuniyandi et al. (2025)

Microplastics in food products and beverages

MPs enters the food chain through multiple contamination pathways. Particles released from industrial activities, i.e. agricultural practices, wastewater streams and plastic waste can be transported through water, soil and air, ultimately reaching food matrices (Domenech & Marcos, 2021). Consequently, contamination may occur at multiple stages of the food chain, from primary production to processing, packaging and retail distribution (Liu et al. 2021; Habib et al. 2022a). Table 2. provides a comprehensive overview of scientific studies investigating the presence of MPs in various food and beverage matrices. The studies provide evidence that MPs contamination is not restricted to a single food category, but occurs across diverse matrices of both liquid and solid foods. Among the analyzed products, water (Wiesheu et al., 2016; Kosuth et al., 2018; Zuccarello et al., 2019), alcoholic (Prata et al., 2020; Shruti et al., 2020) and non-alcoholic beverages (Shruti et al. 2020), milk (Kutralam-Muniasamy et al., 2020), vinegar (Makhdoumi et al., 2021), honey (Mühlschlegel et al., 2017), sea salt (Kim et al., 2018), instant rice (Dessi et al. 2021) and vegetables (Dong et al. 2021) have all been reported to contain microplastic particles.

The interpretation and comparison of these findings are challenging due to the lack of fully standardized analytical protocols for MPs isolation, identification and quantification in complex food matrices. Differences in sample preparation, detection limits, polymer identification techniques and reporting units substantially affect the reported concentrations, thereby limiting the comparability of results across studies

(Kwon et al., 2020; Liu et al., 2020). Despite these methodological limitations, several consistent trends can be identified across the available scientific literature.

Numerous studies have reported the occurrence of MPs in drinking water, including both tap and bottled water. Kosuth et al. (2018) analyzed tap water samples collected from 14 countries worldwide and detected MPs in 81% of the examined samples. Interestingly, the highest average MPs concentration was observed in the USA, whereas the lowest levels were reported in the European Union.

Furthermore, when the results were categorized according to national development status, a statistically significant difference was identified between developed and developing countries ($p < 0.05$). To be more precise, tap water samples originating from more developed regions, including the European Union, the United States and Lebanon, exhibited a mean MPs density of 6.85 particles/L. On the other hand, samples collected from less developed countries, including Cuba, Ecuador, India, Indonesia and Uganda, showed a lower mean density of 4.26 particles/L. In the same study, MPs were detected in all beer ($n = 12$) and sea salt ($n = 12$) samples analyzed (Kosuth et al., 2018).

Similar results were obtained in the research of Gambino et al. (2022). Authors compared MPs contamination in tap and bottled water and reported significantly higher contamination levels ($p < 0.05$) in bottled water, particularly in products packaged in PET and glass bottles. The occurrence of MPs in bottled water stored in glass containers can be explained by the presence of polymer-containing sealing materials located between the cap and the bottle neck. In addition, repeated opening and closing of plastic bottles, especially when performed more than 100 times, has been identified as an important source of MPs generation through mechanical abrasion. Comparable findings were reported by Singh (2021), who demonstrated that a substantial proportion of the MPs detected in bottled water originated from the same polymeric materials used in the manufacture of bottles and caps. Moreover, MPs concentrations increased by 553 ± 202 particles/L per opening–closing cycle, indicating that bottle handling can significantly contribute to contamination. Furthermore, throughout their production, transportation, storage and use, bottles are exposed to various physical and environmental stressors, including compression, ultraviolet radiation and temperature fluctuations, which may accelerate material degradation and promote the release of MPs particles (Winkler et al., 2019; Gambino et al., 2022).

When the MPs identified in other food products (Table 2) are compared with the polymers most commonly used in food packaging and food-contact materials (Table 1), a clear relationship becomes apparent. PET, PE and PP were among the most frequently detected polymers across the reviewed studies, while these same materials are extensively used in the manufacture of bottles, containers, packaging films and closure systems. This correspondence suggests that food packaging materials may represent an important pathway for the introduction of MPs into foods and beverages, alongside environmental sources of contamination.

Compared with beverages, drinking water, sea salt and seafood, the occurrence of MPs s in meat and meat products has received comparatively limited scientific attention. Table 3. presents a systematic overview of studies evaluating the occurrence of MPs in meat and meat products, including the animal species investigated, anatomical location, polymer composition and reported contamination levels. The studies have reported the presence of MPs in both animal-derived and plant-based (Milne et al. 2024) meat products, including poultry (Chen et al 2023; Milne et al., 2024), beef (Visentin et al., 2024), and pork (van der Veen et al., 2022), suggesting that contamination may occur across diverse protein sources. MPs contamination of meat and meat products occurs at several stages of the food chain – by livestock exposure to contaminated feed, drinking water, soil and air, as well as during slaughtering, processing, handling, packaging, storage and distribution (Olmo & Holman, 2025). According to Patrucco et al. (2025), ruminants may be exposed to MPs through two primary pathways. The first involves the direct ingestion of feed already contaminated with MPs particles, whereas the second results from the accidental consumption of larger plastic debris present in feed or the surrounding environment, including improperly discarded plastic bags, ropes and packaging materials.

Table 2 Overview of the studies reporting microplastic occurrence in food products and beverages.
Tablica 2. Pregled istraživanja o prisutnosti mikroplastike u prehrambenim proizvodima i pićima.

Food Product / Namirnica	Country / Zemlja	Number of samples (N) / Broj ćuzoraka (N)	Identified Polymers / Identificirani polimeri	Microplastic Concentration / Koncentracija mikroplastike
Beer / Pivo	Mexico / Meksiko	24	PA, PEA, PET	152 50.97 MP/drink
Energy drinks / energetska pića	Mexico / Meksiko	20	PA, PEA	14 - 5.79 MP/drink
White vine / bijelo vino	Italy / Italija	26	PE	2,563 – 5,857 / L
Bottled mineral water / flaširana mineralna voda	Germany / Njemačka	1	PET	NS
Tap water / voda iz slavine	Cuba (n = 1) / Kuba, Ecuador (n = 24) / Ekvador, England (n = 3) / Engleska, France (n = 1) / Francuska, Germany (n = 2) / Njemačka, India (n = 17) / Indija, Indonesia (n = 21) / Indonezija, Ireland / Irska (n = 1), Italy (n = 1) / Italija, Lebanon (n = 16) / Libanon, Slovakia (n = 8) / Slovačka, Switzerland (n = 2) / Švicarska, Uganda (n = 26) / Uganda, and the US (n = 36) / Sjedinjene Američke Države.	159	NS	0 to 61 /L
Milk / mlijeko	Mexico / Meksiko	23	PSF	6.5 ± 2.3 /L
Vinegar / ocat	Iran / Iran	24	PE, HDPE	51.35 ± 20.73 / L
Honey / med	Switzerland / Švicarska	5	PET	32–108 / kg
Commercially available sea salt / komercijalno dostupna morska sol	Croatia / Hrvatska	1	PP, PE	58 MPs/kg

PA – polyamide / poliamid; PEA - poly(ethylene adipate) / polietilen adipat; PET - polyethylene terephthalate / polietilen tereftalat; PE – polyethylene / polietilen; NS – not stated / nije navedeno; PSF – polystyrene foam / polistirenska pjena.

Table 2 Overview of the studies reporting microplastic occurrence in food products and beverages.
Tablica 2. Pregled istraživanja o prisutnosti mikroplastike u prehrambenim proizvodima i pićima.

Analytical method / Analitička metoda	Particle size / veličina čestica	Particle shape / oblik čestica	Reference / Referenca
micro-Raman spectroscopy / mikro-ramanova spektroskopija; epifluorescence microscopy / epi-fluorescencijska mikroskopija	100–3000 µm	fibers / vlakna; fragments / fragmenti	Shruti et al. (2020)
micro-Raman spectroscopy / mikro-Ramanova spektroskopija; epifluorescence microscopy / epi-fluorescencijska mikroskopija	100–3000 µm	fibers / vlakna	
micro-Raman spectroscopy / mikro-Ramanova spektroskopija; optical microscopy / optička mikroskopija	26 × 122 µm (medijan / median)	NS	Prata et al. (2020)
micro-Raman spectroscopy / mikro-Ramanova spektroskopija	NS	fibers / vlakna	Wiesheu et al. (2016)
Visual identification by stereomicroscopy with Rose Bengal staining and particle durability testing / vizualna identifikacija stereomikroskopijom uz bojenje Rose Bengalom i test izdržljivosti čestica	fiber length / duljina vlakana: 100 - 5000 µm	fibers / vlakna; fragments / fragmenti; films / filmovi	Kosuth et al. (2018)
micro-Raman spectroscopy / mikro-Ramanova spektroskopija; SEM-EDS for additional characterization / SEM-EDS za dodatnu karakterizaciju	100–5000 µm	fibers / vlakna; fragments / fragmenti	Kutralam-Muniasamy et al. (2020)
Nile Red staining / bojenje nilskim crvenilom; stereomicroscopy / stereomikroskopija; Fourier-transform infrared spectroscopy (FTIR) / FTIR spektroskopija	1 - 500 µm	fragments / fragmenti; vlakna / fibers	Makhdoumi et al. (2021)
Light microscopy / svjetlosna mikroskopija; micro-Raman spectroscopy / mikro-Ramanova spektroskopija; FTIR spectroscopy / FTIR spektroskopija	>30 µm (reported analytical threshold / naveden analitički prag)	fibers / vlakna; fragments / fragmenti	Mühlschlegel et al. (2017)
Stereomicroscopy / stereomikroskopija; Attenuated total reflectance Fourier-transform infrared spectroscopy (ATR-FTIR) / infracrvena spektroskopija s Fourierovom transformacijom i prigušenom totalnom refleksijom (ATR - FTIR)	NS	NS	Kim et al. (2018)

PA – polyamide / poliamid; PEA - poly(ethylene adipate) / polietilen adipat; PET - polyethylene terephthalate / polietilen tereftalat; PE – polyethylene / polietilen; NS – not stated / nije navedeno; PSF – polystyrene foam / polistirenska pjena.

Table 3 Overview of the studies reporting microplastic occurrence in meat and meat products.
Tablica 3. Pregled istraživanja o pojavnosti mikroplastike u mesu i mesnim proizvodima.

Meat Type / Vrsta mesa	Country / Zemlja	Number of samples (N) / Broj uzoraka (N)	Anatomical location / Anatomical location	Identified polymers / Identificirani polimeri	Microplastic concentration / Koncentracija mikroplastike	Analytical method / Analitička metoda	Particle size / veličina čestica	Particle shape / oblik čestica	Reference / Referenca
Poultry / piletina	China / Kina	3	breast muscle / prsni mišić	PA6, PS	565,6 mg / kg		NS	NS	Chen et al. (2023)
	SAD / Sjedinjene Američke Države	6		NS	100 particles/ kg (čestica po kilogramu)		≥45 µm (analytical threshold / analitički prag)	NS	Milne et al. (2024)
	SAD / Sjedinjene Američke Države	12	nuggets / pileći medaljoni		310 particles / kg (čestica po kilogramu)		≥45 µm (analytical threshold / analitički prag)	NS	
Beef / govedina	Italy / Italija	10	hamburgers / hamburgeri	> 18	PC: 30 300 particles / kg; PE: 1 580 particles / kg; PP: 750 particles / kg (čestica po kilogramu)	Micro-Fourier-transform infrared spectroscopy in attenuated total reflectance mode (µ-FTIR-ATR) / Mikro-FTIR spektroskopija s prigušenom totalnom refleksijom	30–3154 µm	fragments / fragmenti ; fibers / vlakna; beads / kuglaste čestice	Visentin et al. (2024)
Plant-based ground beef / biljni nadomjestak mljevene govedine	SAD / Sjedinjene Američke Države	8	-	NS	0,06 particles / g (čestica po gramu)	Stereomicroscopy and Raman spectroscopy / stereomikroskopija i Ramanova spektroskopija	≥45 µm (analytical threshold / analitički prag)	NS	Milne et al. (2024)
Pork / svinjetina	Netherlands / Nizozemska	8	NS	PE, PVC, PP	PE: 88 - 690 mg/ kg, PVC: 127 mg / kg, PP: 63 mg / kg	Accelerated solvent extraction (ASE) and double-shot pyrolysis–gas chromatography–mass spectrometry (Pyr-GC/MS) / Ubrzana ekstrakcija otapalom i pirolizna plinska kromatografija s masenom spektrometrijom	NS	NS	van der Veen et al. (2022)

Furthermore, approximately 72 % of foreign bodies identified in the rumen of domestic cattle are of plastic origin, with plastic bags accounting for 65,5 % of these materials. In addition, plastic products are extensively used in livestock production systems, particularly for covering silage and wrapping hay bales. Plastic films used for bunker silage preservation represent approximately 33 - 45 % of the total plastic materials utilized on dairy farms. As these materials undergo weathering and degradation under environmental conditions, they may release MPs particles into animal feeds (Patrucco et al., 2025).

Although plastic packaging is frequently considered one of the major sources of MPs in food products, contamination also occurs during food processing. Plastic cutting boards, transport containers and other equipment that come into direct contact with meat release MPs particles, as a result of mechanical abrasion (Čapla et al., 2026). In particular, plastic cutting boards have emerged as a significant source of contamination. Habib et al. (2022a) demonstrated that mechanical abrasion of polyethylene cutting surfaces can result in the transfer of MPs particles to meat. Short-term washing of meat was ineffective in removing MPs, whereas prolonged rinsing for 3 min reduced contamination levels to 0.07 MPs/g of meat. Furthermore, analysis of worn cutting boards revealed that approximately 875 g of polyethylene may be lost over the lifetime of a single board, highlighting their considerable potential as a source of MPs generation.

Similar results were reported by Habib et al. (2022b), who detected MPs contamination in chicken and fish samples purchased from markets, retail stores and supermarket chains in the Middle East. MPs concentrations in chicken ranged from 0.03 ± 0.04 to 1.19 ± 0.72 particles/g of meat, while fish samples contained between 0.014 ± 0.024 and 2.6 ± 2.8 particles/g. The authors again identified polyethylene-based cutting boards as the primary source of contamination, with higher MPs concentrations observed in products cut from the bone compared with fillets prepared on non-plastic surfaces.

Conclusion

Microplastics are increasingly detected across diverse food and beverage matrices, indicating that dietary intake represents an important route of human exposure. Their presence in water, salt, beverages, vegetables, meat and meat products raises concerns regarding potential adverse effects on human health. However, comparison among studies remains limited due to the lack of harmonized analytical protocols for microplastic extraction, identification and quantification. Therefore, standardized methods are essential to ensure reliable, reproducible and comparable results. Furthermore, reducing microplastic contamination requires actions beyond analytical improvement, including lower plastic consumption, responsible use of food-contact plastics, improved waste management and public awareness campaigns focused on reducing plastic waste and its proper disposal.

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Mikroplastika u prehrambenim proizvodima: pregled trenutnih istraživanja

Sažetak

Kontinuirani porast primjene plastike u prehrambenoj industriji potaknuo je brojna istraživanja o mikro - i nanoplastici, kao novim kontaminantama hrane. Zbog otpornosti i spore razgradnje, a pod utjecajem niza okolišnih čimbenika, plastični materijali se postupno usitnjavaju u manje čestice koje dospijevaju u vodu, tlo, zrak i sirovine. Time mikro – i nanoplastika postaju relevantno pitanje sigurnosti hrane. Ovaj rad prikazuje dosadašnje znanstvene spoznaje o prisutnosti mikroplastike u hrani i pićima, s naglaskom na moguće izvore i puteve kontaminacije. Posebna pozornost posvećena je namirnicama i pićima u kojima je mikroplastika najčešće potvrđena, uključujući vodu, mlijeko, alkoholna i bezalkoholna pića, sol, med, povrće te meso i mesne proizvode. Uočeno je da su polietilen, polipropilen i polietilen-tereftalat među najčešće detektiranim polimerima u hrani, što se povezuje s njihovom širokom primjenom u bocama, spremnicima, folijama, zatvaračima i drugim materijalima koji dolaze u kontakt s hranom. Osim ambalaže, izvori kontaminacije mogu uključivati okoliš, vodu, stočnu hranu, proizvodne površine, procesnu opremu te plastične daske za rezanje. Dostupna istraživanja upućuju na to da mikroplastika nije ograničena na pojedinačnu skupinu namirnica, nego je zabilježena u različitim tekućim i krutim prehrambenim proizvodima. Ipak, usporedivost objavljenih rezultata znatno je ograničena zbog razlika u metodama uzorkovanja, ekstrakcije, identifikacije i kvantifikacije. Stoga bi buduća istraživanja trebala biti usmjerena na razvoj i standardizaciju analitičkih metoda, jasnije određivanje izvora kontaminacije te smanjenje uporabe plastike i poboljšanje gospodarenja plastičnim otpadom.

Ključne riječi: mikroplastika, kontaminacija hrane, materijali pakiranja hrane, sigurnost hrane

Mikrokunststoffe in Lebensmitteln: Ein Überblick über den aktuellen Forschungsstand

Zusammenfassung

Der stetig steigende Einsatz von Kunststoffen in der Lebensmittelindustrie hat zahlreiche Studien zu Mikro- und Nanokunststoffen als neue Lebensmittelkontaminanten ausgelöst. Aufgrund ihrer Beständigkeit und ihres langsamen Abbaus sowie unter dem Einfluss verschiedener Umweltfaktoren werden Kunststoffe nach und nach in kleinere Partikel zerlegt, die in Wasser, Boden, Luft und Rohstoffe gelangen. Dies macht Mikro- und Nanokunststoffe zu einem relevanten Thema der Lebensmittelsicherheit. Dieser Beitrag stellt den aktuellen wissenschaftlichen Kenntnisstand zum Vorkommen von Mikrokunststoffen in Lebensmitteln und Getränken dar, wobei der Schwerpunkt auf möglichen Quellen und Kontaminationswegen liegt. Besondere Aufmerksamkeit gilt den Lebensmitteln und Getränken, in denen Mikroplastik am häufigsten nachgewiesen wurde, darunter Wasser, Milch, alkoholische und alkoholfreie Getränke, Salz, Honig, Gemüse sowie Fleisch und Fleischprodukte. Polyethylen, Polypropylen und Polyethylenterephthalat gehören zu den am häufigsten nachgewiesenen Polymeren in Lebensmitteln, was auf ihre weit verbreitete Verwendung in Flaschen, Behältern, Folien, Verschlüssen und anderen Materialien mit Lebensmittelkontakt zurückzuführen ist. Neben Verpackungen können auch die Umwelt, Wasser, Tierfutter, Produktionsflächen, Verarbeitungsanlagen und Schneidebretter aus Kunststoff als Kontaminationsquellen dienen. Die vorliegenden Forschungsergebnisse deuten darauf hin, dass Mikroplastik nicht auf eine einzige Lebensmittelgruppe beschränkt ist, sondern in einer Vielzahl von flüssigen und festen Lebensmitteln nachgewiesen wurde. Die Vergleichbarkeit der veröffentlichten Ergebnisse ist jedoch aufgrund von Unterschieden bei den Probenahme-, Extraktions-, Identifizierungs- und Quantifizierungsmethoden erheblich eingeschränkt. Daher sollte sich die zukünftige Forschung auf die Entwicklung harmonisierter Analysemethoden, eine klarere Definition von Kontaminationsquellen sowie die Reduzierung des Kunststoffverbrauchs und die Verbesserung der Kunststoffabfallbewirtschaftung konzentrieren.

Schlüsselwörter: Mikroplastik, Lebensmittelkontamination, Lebensmittelverpackungsmaterialien, Lebensmittelsicherheit

Microplásticos en productos alimenticios: revisión de la investigación actual

Resumen

El aumento continuo del uso de materiales plásticos en la industria alimentaria ha impulsado numerosas investigaciones sobre los microplásticos y nanoplásticos como nuevos contaminantes de los alimentos. Debido a su resistencia y lenta degradación, y bajo la influencia de diversos factores ambientales, los materiales plásticos se fragmentan progresivamente en partículas de menor tamaño que pueden llegar al agua, el suelo, el aire y las materias primas. De este modo, los microplásticos y nanoplásticos se han convertido en una cuestión relevante para la seguridad alimentaria. Este trabajo presenta los conocimientos científicos disponibles hasta la fecha sobre la presencia de microplásticos en alimentos y bebidas, con especial atención a sus posibles fuentes y vías de contaminación. Se presta especial atención a los alimentos y bebidas en los que se ha confirmado con mayor frecuencia la presencia de microplásticos, entre ellos el agua, la leche, las bebidas alcohólicas y no alcohólicas, la sal, la miel, las hortalizas, así como la carne y los productos cárnicos. Se ha observado que el polietileno, el polipropileno y el tereftalato de polietileno se encuentran entre los polímeros detectados con mayor frecuencia en los alimentos, lo que se relaciona con su amplio uso en botellas, recipientes, películas plásticas, tapones y otros materiales que entran en contacto con los alimentos. Además de los materiales de envasado, las fuentes de contaminación pueden incluir el medio ambiente, el agua, los piensos, las superficies de producción, los

equipos de proceso y las tablas de corte de plástico. Las investigaciones disponibles indican que la contaminación por microplásticos no se limita a un grupo específico de alimentos, sino que se ha detectado en diversos productos alimenticios, tanto líquidos como sólidos. No obstante, la comparabilidad de los resultados publicados está considerablemente limitada por las diferencias existentes en los métodos de muestreo, extracción, identificación y cuantificación. Por ello, las futuras investigaciones deberían centrarse en el desarrollo de métodos analíticos armonizados, una determinación más precisa de las fuentes de contaminación, así como en la reducción del uso de plásticos y la mejora de la gestión de los residuos plásticos.

Palabras claves: microplásticos, contaminación de los alimentos, materiales de envasado alimentario, seguridad alimentaria

Microplastiche nei prodotti alimentari: una panoramica delle ricerche attuali

Riassunto

Il continuo aumento dell'impiego della plastica nell'industria alimentare ha stimolato numerose ricerche sulle microplastiche e nanoplastiche quali nuovi contaminanti degli alimenti. A causa della loro resistenza e lenta degradazione e sotto l'influenza di una serie di fattori ambientali, i materiali plastici si frammentano gradualmente in particelle più piccole che raggiungono l'acqua, il suolo, l'aria e le materie prime. Le microplastiche e le nanoplastiche diventano così una questione rilevante per la sicurezza alimentare. Il presente lavoro illustra le conoscenze scientifiche finora acquisite sulla presenza di microplastiche negli alimenti e nelle bevande, con particolare attenzione alle possibili fonti e vie di contaminazione. Particolare attenzione è dedicata agli alimenti e alle bevande nei quali è stata più frequentemente accertata la presenza di microplastiche, tra cui acqua, latte, bevande alcoliche e analcoliche, sale, miele, ortaggi, nonché carne e prodotti a base di carne. È stato osservato che il polietilene, il polipropilene e il polietilene tereftalato sono tra i polimeri più frequentemente rilevati negli alimenti, circostanza riconducibile al loro ampio impiego in bottiglie, contenitori, pellicole, chiusure e altri materiali destinati al contatto con gli alimenti. Oltre agli imballaggi, le fonti di contaminazione possono comprendere l'ambiente, l'acqua, i mangimi, le superfici di produzione, le attrezzature di processo e i taglieri in plastica. Gli studi disponibili indicano che la presenza di microplastiche non è limitata a un singolo gruppo di alimenti, ma è stata rilevata in diversi prodotti alimentari liquidi e solidi. Tuttavia, la comparabilità dei risultati pubblicati è notevolmente limitata dalle differenze nei metodi di campionamento, estrazione, identificazione e quantificazione. Pertanto, le ricerche future dovrebbero essere orientate allo sviluppo di metodi di analisi armonizzati, a una più chiara individuazione delle fonti di contaminazione, nonché alla riduzione dell'uso della plastica e al miglioramento della gestione dei rifiuti plastici.

Parole chiave: microplastiche, contaminazione degli alimenti, materiali di imballaggio alimentare, sicurezza alimentare