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Microplastic Contamination of Dairy and Bakery Products: Sources and Effects on Human Health—A Review

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ABSTRACT

The widespread environmental presence of microplastics and their ability to enter the food chain are resulting in food contamination by these particles, which has been a serious health problem for the public. Products often consumed in the dairy and bakery industries are becoming more vulnerable to contamination by microplastics that come from packaging, processing, and the environment. The new findings of the studies on the long-term health impacts due to the ingestion of microplastics point to some serious health hazards. The findings of analyses on the availability of microplastics in dairy and bakery products are summarized in this review paper, along with the sources of contamination, classification of microplastics, and their health impact. This paper can present an overview for future studies on contamination of dairy and bakery products by microplastics, which is important for the strategies to reduce the contamination of the two top-growing food sectors.

1 | Introduction

Plastics have been made from fossil fuels for more than a century. The usage of plastic has increased exponentially as it has been identified as a multipurpose material (Jayasinghe et al. 2023). It is constantly passing through various human activities such as building materials, equipment, plastic packing, clothes, etc. (Shen et al. 2020). Plastics come with the limitation of recycling, as they are targeted for a single use, resulting in the increase in production around the globe, resulting in increased pollution by plastic due to the generation of plastic waste (Lau et al. 2020). Since 1950, the global production of plastics has been 8300 million metric tons (Geyer et al. 2017). The plastic production touched 368 million metric tons around the globe in 2019, and within 20 years the amount is expected to double (Lebreton and Andrady 2019). Although the multiple applications of plastics have greatly improved our lives, they come with drawbacks of major concern, such as particles of plastic spread in all areas of the environment (Al Mamun et al. 2023).

Abbreviations: AFM, atomic force microscopy; BPA, bisphenol A; EDC, endocrine-disrupting chemical; FTIR, Fourier-transform infrared spectroscopy; MP, microplastic; PC, polycarbonate; PE, polyethylene; PET, polyethylene terephthalate; SEM, scanning electron microscopy; TEM, transmission electron microscopy.

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Because of the different environmental processes such as physical, chemical, and biological action, plastic wastes can slowly degrade and generate numerous smaller plastic fragments (K. Zhang et al. 2021). These particles were termed "microplastics" (Galloway and Lewis 2016). Microplastics can invade the human body by means of exposure pathways, such as skin contact, inhalation, and ingestion, after undergoing processes, such as buildup, degradation, and migration, under varied conditions of the environment (Prata et al. 2020). Improper disposal methods can be considered as the common cause of microplastic contamination (Jayasinghe et al. 2023). Microplastics can easily access the human food chain since plastics can easily resist degradation and can remain for extended periods in the environment (Al Mamun et al. 2023). Microplastics are often found in drinking water, food, and many other environmental areas, which has led to a growing worldwide concern about them (C. Wang et al. 2021).

The availability of microplastics has been reported in 15 body parts of human beings. Their occurrence varies among the different body parts that include the placenta, liver, and lungs (Kutralam-Muniasamy et al. 2023). Each person is exposed to 1,036 particles of microplastic daily through food Yadav et al. (2022). When packaging of food products is made up of synthetic plastics, health hazards can result due to the leakage of the materials into the products (Jayasinghe et al. 2023). According to Cox et al. (2019), 39–52 thousand microplastic items per capita per year can be exposed from the foods that cover 15% of the calorie requirement of the body. Information about the number of MPs in different food items is the best way to be aware of the microplastic contamination of food (Chakraborty et al. 2024).

The demand for bakery products has changed, and there is now an increased demand for a variety of baked products (Nicolosi et al. 2023). Newswire (2021) forecasted that the global market for ingredients used in baking would reach 22.3 billion USD by the year 2026. In 2020, the production of milk around the globe reached about 906 million metric tons, which is further expected to grow in the future (Kondaridze and Luckstead 2023). The market of the dairy industry was estimated to be USD 871 billion in 2021, and an increase of about USD 257 billion is predicted in the next 5-year period (Strateanu et al. 2023).

Microplastics are recognized as an emerging pollutant of the environment as well as a growing food contaminant (Jambeck et al. 2015), which has been receiving considerable attention in recent studies (Q. Chen et al. 2021). Despite gaining worldwide attention, studies are more focused on environmental contamination, water, seafood, and so on, with limited studies on dairy and bakery products—the two most crucial sections of the human diet.

Both dairy and bakery product markets have been growing amazingly worldwide. Despite growing health awareness, substantial knowledge gaps remain in understanding MP contamination levels in these targeted food groups. Therefore, this review evaluates the limited studies performed on the contamination of MPs in the two top-growing food-industry markets of dairy and bakery products, which can increase the focus of studies directed toward contamination of dairy and bakery products and strategies to mitigate the problems in the future. Furthermore, the possible sources of microplastic contamination along with their health impact are also discussed.

2 | Formation and Classification of Microplastics

The breakdown of plastic waste formed microplastics under different environmental factors (El Hadri et al. 2020). As the degrading process progressed, more microplastics were formed (Tong et al. 2022). It may be led by the biological, physical, and chemical activities (Jahnke et al. 2017). The breakdown of plastic waste affects its mechanical and chemical properties, leading to the formation of small plastic fragments. Microplastics are these fragments with a size < 5 mm (K. Zhang et al. 2021). Plastic does degrade in the environment, but primarily in surface water or along the shore due to physical abrasion mechanisms and UV light (Barnes et al. 2009).

Schwabl et al. (2019) revealed that polypropylene and polyethylene terephthalate made up over 80% of the microplastics were detected in human excrement. The most common microplastics found in food are 22.8% polyethylene, 22% polyethylene terephthalate, and 19% polypropylene, which are used for food packaging and plastic bottles (Geyer et al. 2017). Smaller, fiber-shaped microplastics are generally more toxic, with their impact depending on exposure duration and the way they interact with the body (Pirsaheb et al. 2020). The detailed classification of microplastics recorded to this date are included in Table 1 and possible illustration of MPs is shown in Figure 1.

3 | Sources of Contamination

Packaging of food items can lead to the presence of microplastics in the products (Jadhav et al. 2021), which has been confirmed by studies performed on different food products (Du et al. 2020). The food products also can often be contaminated by the presence of impurities from processing materials and contaminants present in the packaging (Liebezeit and Liebezeit 2014). It is clear that processed foods are more likely to contain MPs than unprocessed foods, and thus these foods, when fed, contribute more to the human exposure to microplastics (Senathirajah et al. 2021). Moreover, there are possibilities of microplastics from the environment contaminating the raw materials (Borriello et al. 2023).

Consequently, microplastics are introduced into the food chain during the production of agricultural produce through air, water, and soil. Additionally, different steps in the food supply chain, such as post-harvest handling, packaging, processing, transportation, and storage, are contributing significantly to the microplastic contamination (Jayasinghe et al. 2023). The sources of contamination of dairy and bakery products by MPs is shown in Figure 2.

TABLE 1 | Classification of microplastics (MPs).

Microplastic	Classification	Description	References
Based on origin	Primary	Primary MPs are composed of tiny particles that are purposely produced in "micro" size in industries and spread in the environment either by accidents or by their uses.	Alomar et al. (2016); Masura et al. (2015)
	Secondary	The fragmentation of bigger plastics results in the formation of secondary MPs.	
Based on color	Blue; white; red; transparent; black; green; pale yellow; and cream	The visible color of the microplastic may depend on the original color of the plastic object or the degradation pathway that is carried out by the polymer. It also depends on the external contaminants. The types of contaminants they have absorbed can be identified from the color of the microplastics; for instance, persistent organic pollutants contamination results to black- or yellow-colored MPs.	J. Frias et al. (2018); Borriello et al. (2023); Crawford and Quinn (2016); Hidalgo-Ruz et al. (2012)
Based on size	Large microplastic	Size ranging to 5 mm	Bermúdez and Swarzenski (2021); Hanvey et al. (2017)
	Meso-size	Size ranging from 200 to 2000 μm	
	Micro-size	Size ranging from 20 to 200 μm	
	Nano-size	Size ranging from 2 to 20 μm	
	Pico-size	Size ranging from 0.2 to 2 μm	
	Femto-size	Size range < 0.2 μm	
Based on shape	Beads; expanded polystyrene; fibers; filaments; films; foams; fragments; grains; granules; lines; pellets; spheres; sponge; rope; and rubber	Microplastic particles exhibit highly heterogeneous morphologies.	J. P. Frias and Nash (2019); Lusher et al. (2020)

FIGURE 1 | Possible illustration of microplastic particles of different colors, shapes, and sizes.

3.1 | Environmental Pathways for the Contamination in Production

Agricultural practices are the main sources of contamination of the soil by microplastics, especially by the usage of plastic mulches to increase the crop production and sewage sludge aimed at altering the soil (Nizzetto et al. 2016). Soil contamination is primarily dominated by PE and PP, but smaller amounts of PVC and PET are also detected (Koelmans et al. 2019), which are widely used in films used in vegetables and fruits and agriculture (He et al. 2015). Over a period of time, they are fragmented into macro, micro, and nano plastics after accumulation in the soil of agricultural lands (Steinmetz et al. 2016). The pathway of soil and water contamination could be through the use of compost (Li et al. 2019), sewage sludge (van den Berg et al. 2020), littering (W. Wang et al. 2020), irrigation (Jiang et al. 2023), atmospheric deposition (Adhikari et al. 2024), and plastic mulching (Khalid et al. 2023).

In addition, agricultural plants likely absorb MPs (Gan et al. 2023). According to several studies, roots can absorb and store MPs with small diameters, and they are transported to the other tissues of plants (Zhu et al. 2022). Additionally, edible plant portions such as leaves, stems, and fruit can accumulate these microplastic particles, resulting in the high exposure of MPs to humans (Conti et al. 2020). A study conducted on a dairy farm in Italy by Patrucco et al. (2024) reported the presence of microplastics in all ryegrass hay samples, with an average of 39,300 MPs per kilogram.

Maganti and Akkina (2023) reported the presence of PET microplastics ranging between 89 and 326 g per kilogram in all the collected samples of the diet of dairy cows in India. These

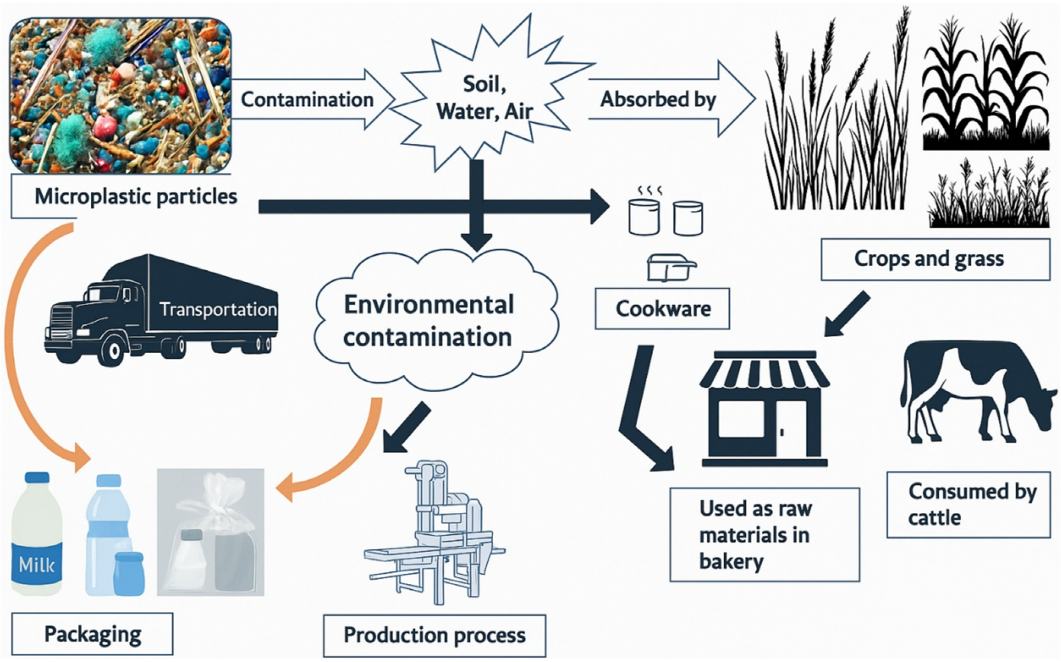

FIGURE 2 | Possible sources of microplastic contamination in bakery and dairy products.

findings can relate that the contamination of soil and water could lead to the accumulation of microplastics in plants and crops, which are later consumed by dairy cattle, leading to the accumulation of MPs inside their bodies. The same contaminated crops can be used as raw materials in the bakery industry and also in the production of dairy feed, which further increases the chances of contamination.

3.2 | Microplastic Contamination During Food Processing

There are several ways that microplastics might contaminate processed foods throughout the food processing process (Zajác et al. 2025). Food items may come into touch with plastic utensils, containers, and equipment during processing, all of which can lead to microplastic contamination. Mechanical forces during processing can further enhance the release of the MPs from the plastics used during processing (Van Cauwenberghe and Janssen 2014).

Studies on the exposure to microplastics from cookware and bakeware are still in their early stages. This requires more detailed studies and informing the consumers about the potential exposure to the microplastics that may release from the cooking and baking wares (Lin et al. 2024). Several cooking appliances, such as plastic boards for cutting, coated non-stick cookware, and disposable serving platters, are known for releasing significant amounts of microplastic particles after each use, which can subsequently be consumed with food (Y. Liu et al. 2024).

According to studies, irrespective of water or detergent, an average sponge for washing dishes with two layers—soft and hard—can release between 100 and 200 microplastic particles (PET and nylon) after 30 s of scrubbing the surface of the glass (Luo, Qi, et al. 2022). Most sensitive to temperature while in use are food containers, such as plastic boxes, bottles, and cups, resulting in contamination of the food by the leakage of microparticles of plastic (Zheng et al. 2023).

The contamination can also occur during transportation of food products wrapped in plastic packaging or carried in plastic containers. Friction created between the plastic materials and the food products during transportation can result in the plastic breaking down and contaminating the products with MPs (Seghers et al. 2022).

3.3 | Microplastics From Packaging

Q. Zhang et al. (2023) studied the hypothesis that packaging releases microplastics. Du et al. (2020) reported that each person consumes 2977 microplastic particles per year, resulting from the use of take-out containers used in food products. Boxed milk powder contains more microplastics than canned milk due to the PE and aluminum foil lamination that is used in inner packaging (Q. Zhang et al. 2023). Polycarbonate (PC) plastic that comes from leaching is the major cause of exposure of humans to bisphenol A (BPA). Bottles made up of PC used for over a week make an increase in BPA concentration in human urine (Carwile et al. 2009). 0.46–250 particles per cm are released by the opening of plastic packaging (Sobhani et al. 2020). Q. Zhang et al. (2023) found that infants consuming milk powder were exposed to microplastic. The exposure to microplastics due to the feeding bottle was 6.8 times greater than the milk powder.

4 | Microplastics in Dairy Products

Milk and its products are considered a high-quality consumed food as a result of their significant nutritional value (Haug et al. 2007). Different samples from geographical regions such as China, Italy, Türkiye, and Mexico evidenced the availability of microplastics in dairy products, milk powder, and breast milk of mothers (Adjama et al. 2024). MPs contamination can occur in a diverse range, from the feeding of cows to the processing and packaging steps of milk production (Diaz-Basantes et al. 2020; Pironti et al. 2021). The result of the study by Basaran et al. (2023) demonstrates that the contamination of milk mainly occurs at the production phase rather than the packaging. So, to reduce its contamination, every step should be improved from the basic production.

The maximum level of 2590 MPs per liter has been found in human breast milk and dairy products (Adjama et al. 2024). A study conducted in Bangladesh investigated commercially available milk brands of dry powders and liquid varieties. It was reported to have 279.47 MP particles per kg on average for powder samples and 182.27 MP particles per liter on average for liquid samples, which resulted in a high pollution load index showing high pollution of microplastics. Polyethylene dominated the categories for microplastic (Chakraborty et al. 2024).

Microplastic was reported in the milk collected from different animals of the Marmara region, Türkiye. The presence of MPs was found in 89% of the samples. Among them, 77% was ethylene propylene, the prominent one from the 7 types of microplastics identified (Rbaibi Zipak et al. 2024).

Analysis of 14 milk brands from the dairy market in Türkiye was carried out. Microplastics with fiber and fragment shapes; polymers of polyethylene terephthalate, polypropylene, polyurethane, nylon-6, and ethylene-vinyl acetate; and red, black, blue, green, gray, and brown colors were found. The average concentration of 6 MP particles per liter was found in the samples. The average daily exposure to microplastics from food for ages 15 and over was 0.21 particles per mL. A total of 64% of milk samples analyzed had a moderate level of microplastic contamination. The microplastic polymer risk index for all milk samples was calculated to have an average value of 255 (Basaran et al. 2023).

Microplastics were detected in fresh raw milk as well as in powdered cow milk products, with concentrations ranging from 204 to 1004 microplastic particles per 100 mL (Da Costa Filho et al. 2021). Q. Zhang et al. (2023) reported the boxed powdered milk with 7 MP particles per 100 g and the canned powdered milk with 4 MP particles per 100 g. The major reason for higher contamination in boxed samples could be the inner packaging used which can release 8–17 MP particles per 100 g of microplastics. Across all analyzed samples Basaran et al. (2023) found 264 microplastics in total. The most dominant microplastics were ethylene-vinyl acetate polymer, black-colored, and of fiber shape (Basaran et al. 2023). Prata (2024) found that milk and milk products reported 7% of the notifications for the presence of plastic materials.

Buyukunal et al. (2023) selected the Ayran production process from Türkiye, and it was reported that salty water had 43 microplastic particles per 100 mL, salt had 33 microplastic particles per 100 g, samples of milk collected from the stage of homogenization and pasteurization had 26 microplastic particles per 100 mL, and the final prepared product had 18 microplastic particles per 100 mL. Microplastic particles ranging from 1 to 150 μm covered about 37.38% of the total contamination, and with 39.3%, ethylene propylene was the most detected polymer. This study showed the possibility of microplastic contamination in dairy production facilities.

In a study by Zipak et al. (2022), a set-type yogurt production process was selected from Istanbul, and it reported a 10-MP number per 100 mL to be present in the raw milk at acceptance and a 28-MP number per 100 mL to be present in the final yogurt prepared. Kour and Bhatt (2022) collected 12 plastic containers of yogurt of four different brands from the local market of Kathmandu, Nepal. The microplastic migration in the samples was found to range from 3.01 to 19.20 mg/kg using 3% acetic acid as a simulant, and when n-heptane was used as a simulant, the migration was 7.22–58.62 mg/kg.

Banica et al. (2024) collected 11 samples of conventional and 6 samples of organic yogurt of 12 popular brands from the Romanian market. The concentration of microparticles in traditional yogurt ranged from 400 microparticles/kg, reported as the lowest, to 4600 microparticles/kg, reported as the highest. The microplastic particles ranged between 800 and 4400 microparticles per kg in organic yogurt (Banica et al. 2024). In a study by Abedi et al. (2025), samples of yogurt and buttermilk were collected from the market of Iran. The average microplastic level ranged from 0.63 to 0.76 items/mL for the samples of yogurt and 0.52 to 0.7 items/mL for the samples of buttermilk.

The exposure of children through daily oral ingestion of MPs is 3.43 times higher than that of adults (Chakraborty et al. 2024). Infants in particular ingest more polycarbonate (PC) and polyethylene terephthalate (PET) microplastics in their daily diet as compared to adults, and their feces are found to be more prone to MPs (J. Zhang et al. 2021). About 42 microplastic particles per 100 g on average were detected in the infant formula. Babies aged from 0 to 6 months are assumed to consume 49 particles of microplastics per day (Kadac-Czapska et al. 2024).

Saraluck et al. (2024) found that 38.98% of breast milk samples were identified as exposed by MPs. The most frequent types of MPs are PP, PE, and PVC. Ragusa et al. (2022) reported MP contamination in 26 out of 34 breast milk samples. Approximately 90% of the microplastics were of dark and brown colors (Saraluck et al. 2024). The contaminated breast milk will directly increase the number of MPs ingested by the infants, as it is the main source of food for them, which will directly impact their health conditions in the future. Abedi et al. (2025) reported the amount of di(2-ethylhexyl) phthalate in dairy products such as buttermilk and yogurt might have a risk of cancer for adolescents as well as adults.

5 | Microplastics in Bakery Products

Prata (2024) found that cereals and bakery products reported 16.2% of the notifications for the presence of plastic materials. Plastic bakeware can be identified as a major source of microplastics, resulting in human exposure (Lin et al. 2024).

According to Luo, Gibson, et al. (2022), during the process of cooking, millions of microplastic particles of Teflon can be released. In contrast to short baking periods, the highest released number of microplastics was after the 3rd cycle of 60 min of baking (Lin et al. 2024). Alene and Teshager (2024) reported that tiny plastic fractions of PP and PE may be released into the bread when polymeric materials undergo heat treatment.

In a study by Pironti et al. (2021), the Italian salt was found to have the highest contamination value of 8000 particles per kg. Di Fiore et al. (2023) reported the average value of 1653 MPs/kg for sea salt. In a study by Yurtsever and Cüvelek (2024), 19 samples of mixed varieties and different brands were collected from supermarkets in Türkiye. Microplastic particles were present in the samples of sugar with a mean value of 29,110 microplastics per 100 g. With respect to the shape of the microplastics, fragment-shaped MPs were dominant with 75%, followed by film with 21%, and fibers were the lowest with 4% (Yurtsever and Cüvelek 2024).

In a study by Aysha et al. (2024), non-branded and branded flour samples, three of each, were collected from Dhaka city, Bangladesh. The mean value recorded for branded flour samples was 2,747 and 6,409 MPs/kg for non-branded flour samples. Based on the shape of MPs particles, fiber-shaped was the most dominant (fibers > fragments > beads > foams > films). The majority of the detected microplastics were transparent and large-sized (> 600 μm; Aysha et al. 2024). The results presented show the contamination of raw materials such as salt, sugar, and wheat flour used for bakery products with microplastics.

6 | Health Effects of Microplastics (MPs)

The median daily intake of MPs ranging from 1 to 5000 μm was found to be 553 particles per person for children and 883 particles per person for adults. According to Mohamed Nor et al. (2021), microplastic intake by the age of 18 can permanently buildup to 8.32×10^3 particles per person and 5.01×10^4 particles per person by the age of 70 years. Microplastics are not just a part of the food chain; rather, the human body can accumulate them and reach the whole body through blood circulation, hence affecting the organs (Sánchez et al. 2022). Microplastics, when entered into the body (Figure 3), can cause damage to the intestine, impact the growth rate of organisms, reduce fertility, and have a prolonged effect (Prata et al. 2020).

Several studies have detected microplastics (MPs) in various human tissues and fluids, indicating their widespread distribution in the body. MPs have been found in lung tissue (Amato-Lourenço et al. 2021), blood samples (Leslie et al. 2022), and feces, confirming their ability to circulate through the bloodstream and be excreted out (W. Huang et al. 2021; Schwabl et al. 2019). Their presence in human colectomy samples (Ibrahim et al. 2021) suggests that MPs can cross the intestinal barrier, while their detection in the placenta (Braun et al. 2021; Ragusa et al. 2021) highlights the link between exposure of the mother to the external environment and her fetus. Microplastics can be stored in living cells and may cause chronic biological effects.

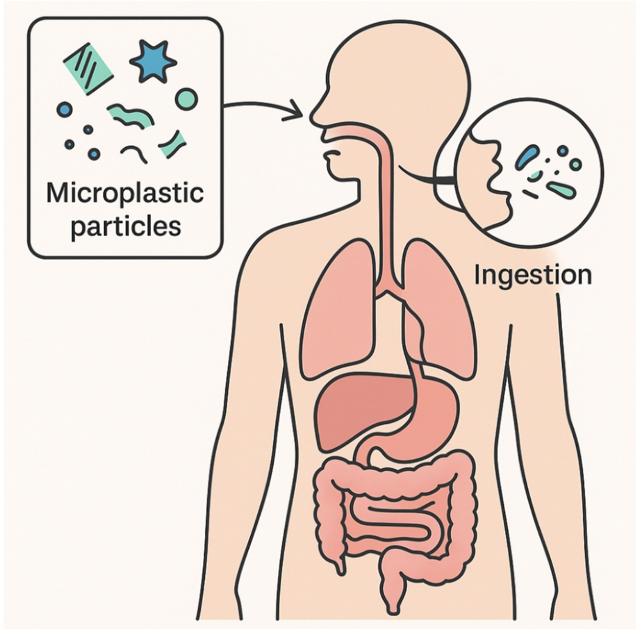

FIGURE 3 | Ingestion of MPs into the human body.

They also have potential health hazards for humans, like alterations in chromosomes, infertility, respiratory problems, gastrointestinal disorders, and immunity (Al Mamun et al. 2023).

6.1 | Toxicity

Microplastics, as a result of aggressive biofilm formation and different surface functional groups, are altered from their original state through weathering and aging processes, making them toxic (X. Liu et al. 2023). Endocrine disruptors such as phthalates and bisphenols are implicated in noncommunicable diseases and toxicity to the human brain (Jayasinghe et al. 2023). The accumulation of microplastic (MP) particles has been shown to affect human health by causing cytotoxic effects, triggering acute reactions such as hemolysis, hypersensitivity, and undesirable immune responses (Hwang et al. 2019).

Ingesting MPs not only has an adverse impact on human health but risks could also arise either from pollutants that are attached to them or by the release of additives by MPs. The toxicity of a substance is connected to its adverse effect on health. The most toxic chemicals, such as endocrine disruptors, are those that can cause cancer, toxic effects on reproductivity, and DNA mutation. The brain, heart, kidney, liver, and reproductive and nervous systems are vulnerable to being affected (Cingotti and Jensen 2019).

Microplastic imposes a higher toxic impact on humans as well as animals, causing neurotoxic, carcinogenic, and endocrine-disrupting effects (Hahladakis et al. 2018). By disrupting the endocrine system, they can impact reproduction, development, and carcinogenesis (Lithner et al. 2011). Endogenous hormones can be mimicked or competed with, and their synthesis can be disrupted by endocrine disruptors such as bisphenol A (BPA) and phthalates (PAEs; Talsness et al. 2009). Furthermore, the fragments of plastic have chemicals adhered to their surface that can enter into the tissues of an organism (Hartmann et al. 2017) and can accumulate in higher amounts through biomagnification, posing an increased risk of toxic effects for humans and animals (Koelmans et al. 2016).

The functioning of hormone-responsive organs is greatly influenced by BPA and PAEs, which have the ability to imitate natural hormones, alter metabolism and synthesis, antagonize their action, or influence receptor expression. These are also significantly linked to a number of diseases, such as testicle, breast, and prostate cancers; metabolic and genital disorders; and asthma and autism (Cingotti and Jensen 2019). Functioning as an androgen antagonist as well as an estrogen agonist, BPA has an impact on reproductive and developmental processes. Additionally, several studies have associated it with risks such as breast cancer, obesity, reproductive disorders, and cardiovascular disease (Cingotti and Jensen 2019).

The exposure of microplastics to the body leads to induced oxidative stress as a result of enhanced reactive oxygen species production and decreased activity of antioxidant enzymes (Bedard and Krause 2007). MPs have been shown to be somewhat immunocytotoxic to human cells (Su et al. 2025). The blood–brain barrier allows microplastics to enter and accumulate in brain tissue, which can affect the release of neurotransmitters and cause neurotoxicity (S. Liu et al. 2024).

Microplastics can absorb various persistent organic pollutants that are present in the environment. That includes polybrominated diphenyl ethers, polychlorinated biphenyls, polycyclic aromatic hydrocarbons, and pesticides, insecticides, and different industrial chemicals (Barletta et al. 2019). Non-polar molecules can easily be absorbed by microplastics as they are hydrophobic in nature. They are also capable of absorbing heavy metals such as aluminum, cadmium, chromium, mercury, zinc, iron, nickel, cobalt, and lead (Rochman et al. 2014).

6.2 | Effect on Reproductive Health

Sperm concentration of men has decreased to one-seventh of its initial value over the past 80 years, which shows that semen quality of men has significantly decreased (C. Zhang et al. 2022). Infertility has affected around 15% of childbearing couples, and this number is going upward every successive year. Male factors account for about half of this problem (Inhorn and Patrizio 2015). In recent years, the effect of microplastics on the reproductive system has drawn more attention (C. Zhang et al. 2022).

According to Zhao et al. (2023), microplastic particles were identified in the testis and semen, with 11.60 particles/g in the testis and 0.23 particles/mL in the semen. Polystyrene (PS) comprised about 67.7% of MPs found in the testis, whereas polyethylene and polyvinyl chloride had dominance in the semen. Various shapes, such as fibers, films, and fragments, were detected in semen, but in the testis, fragments were the main shape. MPs varied from 21.76 to 286.71 μm, with most falling within the range of 20–100 μm (67% in semen and 80.6% in testis).

When mice were exposed for 28 days to microplastics of polystyrene, decreases in testosterone levels and quality of sperm were reported (Jin et al. 2021). Monogononta rotifers, when exposed to microplastics of polystyrene, had decreased fertility and growth rate, a shorter lifespan, and a longer reproductive period (Jeong et al. 2016). Reduced sperm count and quantity, increased rate of sperm malformation, lowered testosterone levels and reproductive capacity, compromised blood–testicular barrier integrity, and a lower survival rate of offspring are all part of the reproductive health effects of microplastics (Ali et al. 2024).

In 6 out of 10 samples taken from men residing in a polluted location in the Campania Region of Italy, 16 pigmented microplastic fragments were found. Their size varied from 2 to 6 μm, and the result showed the presence of polycarbonate (PC), polyoxymethylene (POM), polystyrene (PS), polypropylene (PP), polyethylene (PE), polyethylene terephthalate (PET), polyvinylchloride (PVC), and acrylic (Montano et al. 2023).

6.3 | Effect on Gut Health

Additives and chemicals such as phthalate esters (Deng et al. 2021) can be absorbed by the small-sized microplastics, as well as heavy metals and various toxic substances, causing intestinal damage when ingested (C. Huang et al. 2021). The intestinal flora induced dysbiosis when polyethylene microplastics were accumulated for 21 days, due to the altered antioxidant enzyme activity and histomorphology of the intestine (Xia et al. 2024). Microplastics may disrupt the balance of intestinal microbiota since the digestive system cannot break down microplastics because of their inert character due to their low chemical reactivity (H. Chen et al. 2022). Exposure to 10 mg per L of PE-MPs resulted in a significant growth of the transcript levels of intestinal immunity factors in loach after 21 days of exposure (Xia et al. 2024).

It can be concluded that microplastics can disrupt the intestinal multilayer barrier, as polystyrene microplastics (PE-MPs) were reported in the blood sample, which suggested that the disruption could have caused PE-MPs to enter the bloodstream. Necrosis and apoptosis were significant in blood cells and resulted from the accumulated microplastics in the blood, and this invasion of microplastic particles triggered phagocytosis as a response (Xia et al. 2024).

7 | Detection Techniques for Microplastics

Microplastic detection is divided into physical and chemical characterization (Giri et al. 2024). Microscopy methods are used for physical characterization, such as transmission electron microscopy, atomic force microscopy, scanning electron microscopy, and stereo- and fluorescence microscopy (Sridhar et al. 2022). Although for the chemical characterization, Raman spectroscopy, Fourier-transform infrared spectroscopy, as well as thermal methods, namely pyrolysis–gas chromatography-mass spectrometry, thermogravimetry, differential scanning calorimetry, and/or these methods combined can be used (Tirkey and Upadhyay 2021; Khatoon et al. 2025) mentioned that the most common method widely used for the detection of microplastics is Fourier-transform infrared spectroscopy.

8 | Conclusions and Future Prospects

Microplastic contamination in dairy and bakery products represents an emerging food safety challenge with potential implications for human health. Using contaminated raw materials will lead to the production of contaminated dairy and bakery products. Moreover, consumption of these products will make the population, who are increasing their demand for these top-growing food industries, increase the negative impact on their health due to the ingestion of microplastic particles. More studies should be carried out on the raw materials used in these food sectors and the final products prepared to collect a broader overview.

Consumers are exposed to microplastics from food additives, animal-based and plant-based foods, drinks, and plastic used in food packaging (Al Mamun et al. 2023). To avoid contamination of the food chain by microplastics, replacing plastics with natural materials and recycling plastics can be considered (Jayasinghe et al. 2023). Food industries should make investments in better cleaning systems to stop contamination of microplastics from utensils and equipment. Plastic-free alternatives should be encouraged in production, processing, and packaging. Long-term health risks associated with microplastic ingestion on human health in large populations should be assessed. Future studies can be focused on assessing the major health effects caused by the ingestion of microplastics, advancements in detection technologies to develop accurate methods for quantifying microplastics, and the replacement of plastics in food packaging materials. Addressing this issue requires coordinated efforts between food scientists, toxicologists, policymakers, and industry stakeholders to safeguard public health. Finally, regulatory bodies must establish comprehensive guidelines that limit microplastic exposure in food products while promoting sustainable practices within the food industry. By addressing these priorities, we can move toward a more resilient food system that better protects human health from the emerging threats of microplastic pollution.

Author Contributions

Anish Dangal: conceptualization, visualization, resources, software, writing – original draft, writing – review and editing. **Sangam Dahal:** conceptualization, visualization, resources, software, writing – original draft, writing – review and editing. **Prekshya Timsina:** resources, software, writing – original draft, writing – review and editing. **Khan Irfan Khan:** resources, software, writing – original draft, writing – review and editing. **Annalisa Romano:** software, resources, writing – review and editing. **Angelo Maria Giuffre:** software, resources, writing – review and editing. **Dev Raj Acharya:** software, resources, writing – review and editing. **Kishor Rai:** resources, writing – original draft. **Elena Benedetta Baroncelli:** resources, writing – original draft. **Navin Gautam:** resources, writing – original draft. **Himalaya Ghimire:** resources, writing – original draft.

Ethics Statement

The authors have nothing to report.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

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