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Source, migration path and pollution of microplastics and nano-plastics in food

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Abstract: In this paper, the source, migration path and pollution status of microplastics and nano-plastics in food were reviewed. Microplastics and nano-plastics refer to plastic fragments and particles with diameters less than 5 mm and 1 μm, which enter the food chain through various ways and may eventually accumulate in the human body, posing a potential threat to health. Sources include decomposition of plastic products, direct contact of food with packaging materials, food processing and environmental pollution. The migration path involves the process from environment to food, from food packaging to food, and from food processing to food. The pollution analysis shows that the contents of microplastics and nano-plastics in different foods are different, which are influenced by environmental pollution, production and processing technology, packaging materials, food types and consumption habits. Microplastics and nano-plastics mainly exist in granular and fibrous forms, and may contain a variety of plastic polymers, whose morphology and characteristics affect their absorption, distribution, metabolism and excretion in human body. Health risk research shows that these tiny plastic particles may lead to the damage of intestinal oxidation and inflammation balance, lead to toxic effects such as oxidative stress, inflammation and apoptosis, and may penetrate the epithelial barrier and cause immune response, which has genotoxicity and cytotoxicity. Therefore, this study provides a scientific basis for formulating relevant policies and food safety management, and promotes public attention to microplastics and nano-plastic pollution in food.

1. Introduction

Microplastics refers to plastic fragments and particles with a diameter less than 5 mm, while nano-plastic refers to plastic fragments and particles with a diameter less than 1 micron. Because of their tiny size and special physical and chemical properties, these tiny plastic particles can exist widely in the environment and are difficult to be effectively removed, posing a potential serious threat to human health and ecological environment [1].

As one of the basic needs of human life, the safety of food is directly related to human health. However, with the deepening of research, people gradually found that food may also be contaminated by microplastics and nano-plastics. These tiny plastic particles may enter the food chain through many ways, and eventually accumulate in the human body, which has an unknown impact on human health

[2]. Therefore, it is particularly important to study the source, migration path and pollution status of microplastics and nano-plastics in food. By deeply understanding the source of these tiny plastic particles, their production and release can be reduced from the source; By exploring its migration path, it reveals its propagation law in the food chain; By analyzing its pollution status, the potential risk to human health is evaluated.

This paper comprehensively sorts out and analyzes the sources, migration paths and pollution status of microplastics and nano-plastics in food, so as to provide scientific basis for the formulation of relevant policies and food safety management, and also provide the public with a comprehensive understanding of microplastics and nano-plastics pollution in food, so as to promote the common concern and participation of all sectors of society in solving this environmental problem.

2. Microplastics in food and the source of nano-plastics

2.1. Decomposition of plastic products

The source classification of microplastics and nano-plastics in food is shown in Table 1.

Table 1 Classification table of sources of microplastics and nano-plastics in food

Source category	Specific source	influencing factor
Soil-plant system	Aging and decomposition of plastic films and mulching films used in agricultural activities; Microplastics fibers or fragments contained in sewage sludge and compost are applied to farmland [3].	Soil type, plastic aging degree and application amount
Air deposition	Wear of synthetic textiles, migration and settlement of plastic particles in air	Air flow, particle size
food processing	Wear of plastic processing equipment; Microplastics Migration in Food Packaging Materials	Processing technology, contact time and temperature
Food packaging	Microplastics Migration in Packaging Materials [4].	Type of packaging material, contact time and temperature

Plastic products are everywhere in modern life. From daily necessities to industrial materials, plastics play an important role. However, the life span of plastic products is not infinite, and they will be decomposed gradually by physical, chemical and biological factors in the natural environment. In this process, large plastic products will be broken into smaller pieces, eventually forming microplastics and even nano-plastics. For example, plastic garbage discarded in the ocean will gradually break into tiny particles under the action of waves, wind and sunlight. These particles drift with the current and may be eaten by marine organisms by mistake, and then transmitted to human food through the food chain. Similarly, plastic waste on land may be decomposed into micro-plastic and nano-plastic under the action of weathering and rain erosion, and finally enter food production through soil, water and other ways.

2.2. Food is in direct contact with packaging materials

Food packaging is an important link in food protection, transportation and sales, and plastic materials occupy an important position in food packaging because of their characteristics of portability, durability and waterproof. However, in the process of direct contact with food, plastic packaging materials may release microplastics and nano-plastics.

Some plastic packaging materials may be added with additives such as plasticizers and stabilizers in the production process. These additives may move out of the packaging materials under certain conditions (such as high temperature, acidic or alkaline environment) and react with ingredients in food to form microplastics or nano-plastics. In addition, in the process of transportation, storage and use, plastic packaging materials may also produce tiny plastic particles due to friction, extrusion and other factors, which may adhere to the surface of food or penetrate into food.

2.3. Food processing process

Microplastics and nano-plastics may also be introduced into food processing. In food processing equipment, such as cutting machine, blender, grinder, etc., the wear of plastic parts may produce tiny plastic particles. These particles may be mixed with food during food processing and become the source of microplastics or nano-plastics in food [5]. In addition, some additives or auxiliary materials used in food processing, such as plastic particles as anti-caking agents and thickening agents, may also be directly added to food and become the source of microplastics or nano-plastics. Although the residues of these additives or auxiliary materials in food are usually low, long-term intake may still have potential effects on human health.

2.4. Environmental pollution

Environmental pollution, especially water and soil pollution, significantly affects the content of microplastics and nano-plastics in food. After the plastic waste in water is broken into tiny particles under natural conditions, it is easy to be absorbed by aquatic organisms and passed to human body step by step through the food chain. Similarly, soil pollution is introduced into microplastics and nano-plastics through plastic mulch, sewage irrigation and sludge fertilizer in agricultural production, and these pollutants can be absorbed by crop roots and enter the food chain. Both of them pose potential threats to human health.

3. Migration path of microplastics and nano-plastics in food

The migration path of microplastics and nano-plastics in food is shown in Figure 1:

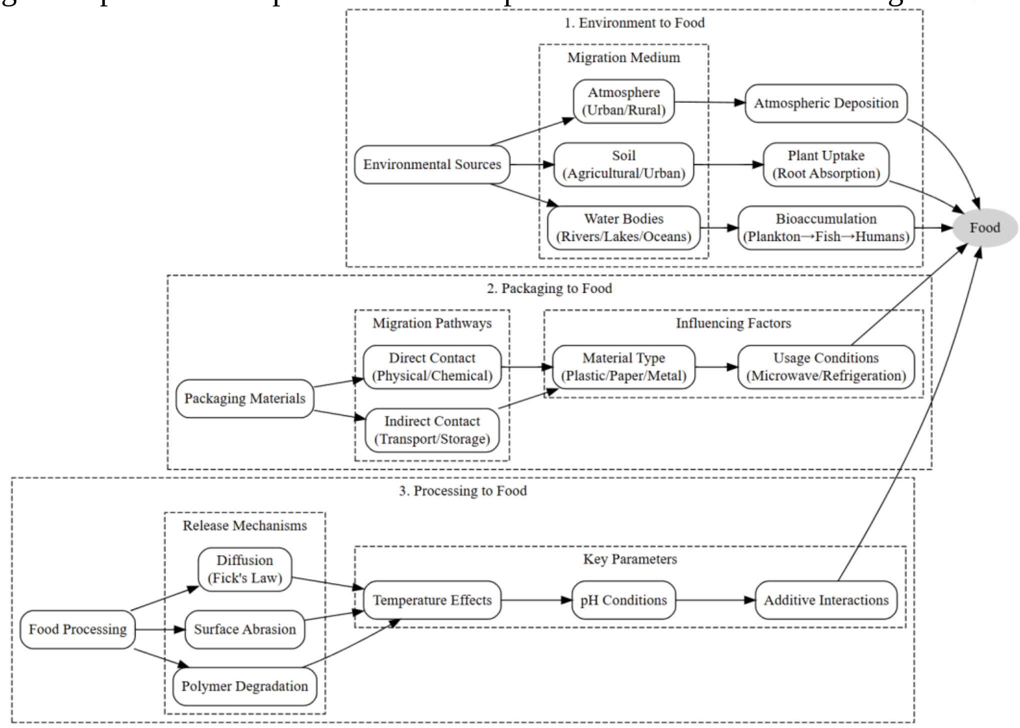

Figure 1 Migration path of microplastics and nano-plastics in food

3.1. From environment to food

Microplastics migrates in the environment and enters the food chain in many ways. Rainfall and surface runoff bring microplastics on land into the water body. After aquatic organisms eat it by mistake, microplastics is transmitted through the food chain, which may eventually affect human beings. In soil, plant roots can absorb microplastics and accumulate it in crops. At the same time, these tiny particles can also penetrate into groundwater, causing deep pollution. Microplastics in the atmosphere can return to the ground through wet and dry deposition, and then enter water or soil, and may also be directly inhaled, affecting the respiratory system. With the transmission of the food chain, the predation process from primary consumers such as plankton to advanced consumers, microplastics gradually rose to human beings, posing a potential threat to health.

Microplastics presents different concentrations and their effects in different environments. In water bodies, rivers, lakes and oceans contain hundreds to thousands of microplastics particles per cubic meter of water, especially in surface seawater near industrial areas. In terms of soil, the content of microplastics in conventional farmland and polluted urban green space can reach hundreds of particles per kilogram, and the pollution of urban green space is more serious. In the atmosphere, the air microplastics concentration in urban areas is significantly higher than that in rural areas, and it can enter the room through outdoor air input and household wear [6]. In food, high levels of microplastics are often detected in seafood such as shellfish and fish, while agricultural products such as vegetables and grains may be polluted by absorbing microplastics in the soil. microplastics is also found in drinking water, but its concentration is usually low.

3.2. From food packaging to food

Microplastics and nano-plastics in food packaging materials can migrate into food through direct and indirect contact. Direct contact migration occurs when packaging materials are in direct contact with food, and it is realized by physical wear or chemical corrosion. Indirect contact migration occurs indirectly through air, moisture and other media during transportation and storage. Different types of packaging materials have different effects on the migration of microplastics and nano-plastics: plastic packaging, such as polyethylene terephthalate (PET) and polyethylene (PE), has higher migration risk [7]; Although the migration risk of paper packaging is low, the plastic coating and adhesive added in the production process may become the source of microplastics; The migration risk of metal packaging is low, but microplastics may be introduced in certain processes.

The usage significantly affects the migration of microplastics and nano-plastics. For example, microwave heating may accelerate the migration process due to thermal expansion and contraction; In contrast, the migration speed under cold storage is slow, but there are still risks in long-term storage; However, under the condition of high temperature cooking, due to thermal decomposition or melting, microplastics and nano-plastics in food packaging materials are more likely to migrate to food.

The migration of microplastics and nano-plastics in food packaging materials into food is a complex process, which is influenced by many factors such as the type of packaging materials and the way of use. In order to reduce the potential risks of microplastics and nano-plastics to human health, it is necessary to strengthen the research on food packaging materials, optimize the production process and improve the safety of packaging materials. At the same time, consumers should also pay attention to the materials and applicable conditions when purchasing and using food packaging, so as to reduce the migration risk of microplastics and nano-plastics.

3.3. From food processing to food

In the process of food processing, the migration of microplastics and nano-plastics is mainly realized by diffusion, surface shedding, dissolution and other degradation methods. According to Fick's diffusion law, nanoparticles move from high concentration area to low concentration area, and then diffuse into food; Nanoparticles located on the surface or cutting edge of polymer may fall off into food. Nanoparticles such as nano-silver can be dissolved into ionic form by oxidation and released into food. Other factors, including photodegradation, thermal degradation, mechanical wear and hydrolysis, will also accelerate the release of nanomaterials into food.

Food processing technology significantly affects the migration of microplastics and nano-plastics. In terms of temperature, microwave heating is more likely to promote the release of nano-materials into food than refrigeration or room temperature. For food simulants, acidic conditions usually promote the dissolution and migration of oxidizable nano-materials (such as nano-silver), but some studies have shown that n-ethane as simulants may lead to higher migration of nano-silver due to its swelling effect on some plastics. In addition, plastic additives added in food packaging, such as antioxidants and light stabilizers, may interact with nanomaterials and affect their migration. The morphology of nano-materials is also very important. Nano-materials coated on the surface are more easily released into food simulants than those melted in the substrate.

Studies have shown that although only a small amount of nanocomposites can migrate from packaging to food or food simulants, there is no consensus on whether these nanocomposites are released in nano-scale form. In addition, the existence of plastic additives will also affect the migration behavior of nanocomposites.

4. Analysis on the Pollution of microplastics and Nano-plastics in Food

4.1. Microplastics and nano-plastics content in different foods

The content of microplastics in drinking water and bottled water is influenced by water source, treatment technology and packaging materials, especially these particles are detected in bottled water. Salt, especially sea salt, may be introduced into microplastics during collection, processing or packaging. The existence of microplastics in honey may be due to bees' contact with environmental pollutants or plastic containers in the production process. Microplastics in beer may come from filtration and packaging in the production process. Seafood is a high-risk food polluted in microplastics, because of the high concentration of microplastics in the marine environment, which is easily transmitted to human beings through the food chain. Rice and tea may also come into contact with microplastics in the process of planting, processing and packaging, especially in the case of using plastic agricultural film or plastic packaging. Although the content of microplastics in some foods such as honey and tea is not high, its universality is still worthy of vigilance. Table 2 below lists and compares the contents of microplastics and nano-plastics in different foods.

Table 2 Comparison Table of microplastics Content in Different Foods

Food category	Microplastics content	Nano-plastic content
bottled water	2.95±2.03 μg/L (PVC), 1.84±2.14 μg/L (PET), 1.86±1.84 μg/L (PE)	There are about 240,000 micro-nano plastic particles per liter, 90% of which are nano-scale
tap water	The detection rate was 81.1%, of which 129 samples contained nano-plastics/microplastics.	After boiling, filtering can remove more than 80%
salt	More than 90% of the salt contains microplastics, and the highest content of microplastics granules per kilogram of sea salt is 681	-
honey	The daily microplastics intake of single-flower honey and multi-flower honey is 1.20 and 0.85 granules/day, respectively [8].	-
beer	About 150 microplastics particles per liter	-
Seafood	Mussels, oysters and scallops are the most polluted in microplastics [9].	-
rice	Every 100 grams of rice contains 3-4 mg of microplastics, and instant rice contains 13 mg	-
tea leaves	The content range is 70-3472 pieces/kg, and the rolling stage in the processing process is the highest, reaching 2266 1206 pieces/kg of tea	-

The contents of microplastics and nano-plastics in food are influenced by many factors, including environmental pollution, production and processing technology, packaging materials, food types and consumption habits. Foods produced in heavily polluted areas often contain high levels of microplastics and nano-plastics; Plastic equipment, containers and additives containing plastic particles used in food production will also increase their content. Plastic packaging materials are an important source of microplastics, and the use of such packaging will significantly increase the microplastics content in food. Different types of foods have different adsorption capacities for microplastics. For example, seafood usually contains a high concentration of microplastics due to the influence of marine environment. Consumers' eating habits are equally important. People who regularly eat plastic packaged foods may consume more microplastics and nano-plastics. Therefore, it is very important to choose environmentally-friendly and safe packaging materials and reduce the use of plastics to reduce the content of microplastics in food.

4.2. Morphology and characteristics of microplastics and nano-plastics in food

Microplastics and nano-plastics in food mainly exist in granular and fibrous forms. The particle size of microplastics is usually less than 5 mm, while that of nano-plastic is less than 1 μm. These tiny plastic particles may come from the wear and tear of food packaging materials, the pollution during food processing or the degradation of plastic waste in the environment. In terms of chemical composition, microplastics and nano-plastics in food may contain various plastic polymers such as polyethylene (PE), polypropylene (PP) and polystyrene (PS).

The morphology and characteristics of microplastics and nano-plastics have an important influence on their absorption, distribution, metabolism and excretion in human body. Granular microplastics may be more easily absorbed by the digestive tract, while fibrous microplastics may form tangles in the intestine, affecting the intestinal function. The particle size distribution determines the ability of microplastics and nano-plastics to penetrate the biological barrier, and the smaller particle size is easier to enter the blood circulation and distribute to various tissues of the whole body. The chemical composition affects the biodegradability and potential toxicity of microplastics and nano-plastics.

Microplastics and nano-plastics can enter the human body through oral intake, respiratory inhalation and skin contact. In the body, they may enter the blood circulation through the intestinal wall and distribute to organs such as liver and kidney. The metabolic process of microplastics and nano-plastics is not completely clear, but they may affect the normal metabolic pathway and lead to metabolic disorder. In terms of excretion, microplastics and nano-plastics may be excreted through urine and feces, but some microplastics may accumulate in the body, and long-term exposure may lead to chronic health problems.

4.3. Health risks of microplastics and nano-plastics in food

Studies have shown that exposure to microplastics and nano-plastics will lead to impaired balance of intestinal oxidation and inflammation, which may lead to toxic effects such as oxidative stress, inflammation and apoptosis. In addition, they may also penetrate the epithelial barrier, cause immune response, have genotoxic and cytotoxic effects, aggravate the inflammation of distal organs, and increase the risk of non-communicable diseases such as cancer, diabetes, cardiovascular disease and chronic lung disease.

The cumulative effect of microplastics and nano-plastics in human body has also attracted wide attention. Studies have shown that these particles have been widely distributed in various organs of human body, and the concentration of microplastics in brain tissue is particularly prominent, which is 7 to 30 times that of kidney and liver samples. Microplastics and nano-plastics released by commercial tea bags during soaking can be absorbed by intestinal cells, and then enter the blood and spread throughout the body. Microplastics and nano-plastics affect health, damage cell proliferation and interfere with microbial metabolic pathways by causing oxidative stress and inflammatory reaction. In particular, polystyrene microplastics can lead to imbalance of intestinal flora and disorder of liver lipid metabolism, while microplastics and nano-plastics may also affect kidney function and have potential effects on nervous system due to high content in brain.

5. Conclusion

Microplastics and nano-plastics enter the food chain mainly through soil-plant system, air deposition, food processing and food packaging, migrate through environmental media such as water, soil and atmosphere, and finally pass on to human beings through the food chain. The content of microplastics in food is influenced by environmental pollution, production and processing technology, packaging materials and consumption habits. Seafood has become a high-risk food due to the high concentration of microplastics in the marine environment, and microplastics has also been detected in daily foods such as bottled water, salt, honey and beer. Health risk assessment shows that these tiny particles may cause intestinal oxidation and inflammation, immune response, genotoxicity and cytotoxicity, and they are widely distributed in various organs of human body, especially in brain tissue with high concentration, which has potential effects on nervous system. Therefore, all sectors of society need to pay attention to microplastics in food, take measures to reduce its production and release, and strengthen food safety management, so as to reduce the potential risks to human health.

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