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Microplastic Contamination and Polymer Characteristics in Meatballs as Indicators of Food Safety in Kambu District, Kendari City, Indonesia

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Abstract

Microplastics have emerged as contaminants of growing concern in food systems due to their persistence in the environment and potential adverse effects on human health. Ready-to-eat foods such as meatballs are widely consumed in Indonesia and may represent a continuous route of microplastic exposure for the population. This study aimed to determine the concentration, physical characteristics, and polymer types of microplastics in meatballs sold in Kambu District, Kendari City, Indonesia. A total of ten meatball samples were collected from different street vendors and analyzed using alkaline digestion with 10% KOH, followed by density separation and filtration. Microplastic particles were identified and characterized based on shape, size, and color using stereomicroscopic observation, while polymer types were determined using Fourier Transform Infrared Spectroscopy (FTIR). The results showed that microplastics were detected in all analyzed samples, with concentrations ranging from 4.00 to 9.00 mg/kg and an average concentration of 6.90 mg/kg. Fragment-shaped microplastics were dominant (54.8%), followed by line/fiber forms (45.2%), with particle sizes ranging from 1.90 to 3.80 mm. FTIR analysis revealed that polyethylene (PE) was the predominant polymer, with a minor possibility of polypropylene (PP), indicating that plastic packaging and food processing equipment are likely sources of contamination. These findings highlight the potential food safety concerns associated with microplastic contamination in street-vended ready-to-eat foods and emphasize the need for improved hygienic practices and monitoring to reduce human exposure through dietary intake.

Keywords: Microplastics; Meatballs; Ready-to-Eat Food; Food Safety; FTIR

1 Introduction

Microplastic pollution has become a global issue that is increasingly gaining attention in the context of food safety and public health. Microplastics are defined as plastic particles smaller than 5 mm that originate from the degradation of larger plastics (*secondary microplastics*) or that are directly produced in small sizes (*primary microplastics*) [1]. These particles are persistent, easily dispersed in the environment, and have been detected in various ecosystem compartments, including air, water, soil, and the food chain [2].

In recent years, the pathway of microplastic exposure through food consumption has become a major concern. Several studies have reported the presence of microplastics in various food materials, such as fish and seafood, salt, drinking water, processed products, and ready-to-eat food [3][4]. Microplastic contamination in food can occur through contaminated raw materials, processing, the use of plastic equipment and packaging, as well as the deposition of particles from ambient air during production and distribution processes [5].

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Meatball is one of the meat-based ready-to-eat foods that is very popular in Indonesia and widely consumed by various age groups. The process of making bakso involves several mechanical stages, such as grinding, mixing, boiling, and serving, most of which use plastic equipment and are often carried out in open environments. These conditions make bakso a food matrix that is potentially contaminated with microplastics, both from processing equipment and from the surrounding environment [7][8]. However, scientific studies on the presence and characteristics of microplastics in meat-based ready-to-eat foods in Indonesia are still relatively limited [8].

In addition to existing as foreign particles, microplastics are also known to carry chemical additives, heavy metals, as well as pathogenic microorganisms that may be released during the digestive process [9]. Recent studies indicate that the size, shape, and type of microplastic polymers play an important role in determining their potential biological impact, including interactions with the human digestive system [10]. Therefore, the presence of microplastics in ready-to-eat foods needs to be taken seriously, even though there are currently no clear regulatory limits [10].

Based on this background, this study aims to analyze the concentration, physical characteristics, and types of microplastic polymers in meatballs sold in the Kambu District, Kendari City. The results of this study are expected to provide a scientific overview of the potential microplastic contamination in ready-to-eat foods and serve as a basis for efforts to improve food safety and protect consumer health.

2 Methods

This study used a descriptive observational design to analyze the concentration, physical characteristics, and types of microplastic polymers in meatballs as ready-to-eat food. A total of ten meatball samples were collected from vendors in Kambu District, Kendari City, with each sample weighing between 20–25 g. The samples were prepared through chemical digestion using a 10% KOH solution to dissolve the organic matrix, followed by density separation and filtration. Microplastics were identified using a stereo microscope to determine the number, shape, color, and size of the particles, while the type of polymer was determined using Fourier Transform Infrared Spectroscopy (FTIR) by comparing the absorption spectrum against a standard library. The data were analyzed descriptively in a quantitative manner, and microplastic concentration was expressed in mg/kg.

3 Results

Microplastics were found in all meatball samples that were analyzed. The number of particles varied among the samples, with concentrations ranging from 4.00 to 9.00 mg/kg. The dominant forms of microplastics were fragments and fibers. Particle sizes ranged from 1.9 to 3.8 mm. FTIR analysis results showed that the most commonly found polymer was polyethylene (PE).

3.1 Microplastic Concentration in Meatball Balls

Table 1 Distribution of Microplastic Concentration (C) in Meatball Balls in Kambu District, Kendari City

Sample Code	Sample Weight (Kg)	Number of MP Particles	Average Size (mm)	Total M (mg)	Microplastic Concentration (mg/Kg)
PB 1	0.020	4	1.90	0.080	4.00
PB 2	0.021	5	2.20	0.105	5.00
PB 3	0.022	6	2.45	0.132	6.00
PB 4	0.023	5	2.70	0.138	6.00
PB 5	0.024	6	2.95	0.168	7.00
PB 6	0.020	7	3.10	0.160	8.00
PB 7	0.021	8	3.35	0.189	9.00
PB 8	0.022	6	3.00	0.154	7.00
PB 9	0.024	7	3.50	0.192	8.00
PB 10	0.025	8	3.80	0.225	9.00

Minimum	**0.020**	**4**	**1.90**	**0.080**	**4.00**
Maximum	**0.025**	**8**	**3.80**	**0.225**	**9.00**
Average	**0.022**	**6.2**	**2.99**	**0.154**	**6.90**

Source: Primary Data 2025

Based on Table 1, the analysis of 10 meatball samples in Kambu District, Kendari City, showed that all samples contained microplastics with varying concentration levels. The weight of the samples analyzed ranged from 20–25 grams, with the number of microplastic particles between 4 and 8 particles per sample and an average size ranging from 1.90–3.80 mm. The total mass of identified microplastics ranged from 0.080–0.225 mg, resulting in microplastic concentrations of 4.00–9.00 mg/kg with an average value of 6.90 mg/kg.

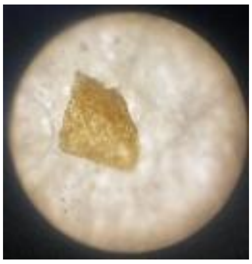
Table 2 Characteristics of Microplastics Based on Their Shape and Quantity

Types of Microplastics	Number of Particles (n)	Percentage (%)
Line/Fiber	28	45.2
Fragmen	34	54.8
Total	62	100

Source: Primary Data 2025

In Table 2, the analysis results show that fragment microplastics are the most dominant type with 34 particles (54.8%), followed by line/fiber microplastics with 28 particles (45.2%).

Table 3 Characteristics of Microplastics Based on Color and Type/Form

	
(Red) *Line/Fiber*	(Yellowish Brown) *Fragmen*

Source: Primary Data 2025

Table 4 Based on Microplastic Size in Meatball Samples

Sample Code	Microplastic Size (mm)
PB1	1.90
PB2	2.20
PB3	2.45
PB4	2.70
PB5	2.95
PB6	3.10
PB7	3.35
PB8	3.00
PB9	3.50
PB10	3.80

Minimum	1.90
Maximum	3.80
Average	2.99

Source: Primary Data 2025

In Table 4 Measurement Results, the microplastics found in the meatball samples ranged in size from 1.90 to 3.80 mm, with an average value of 2.99 mm.

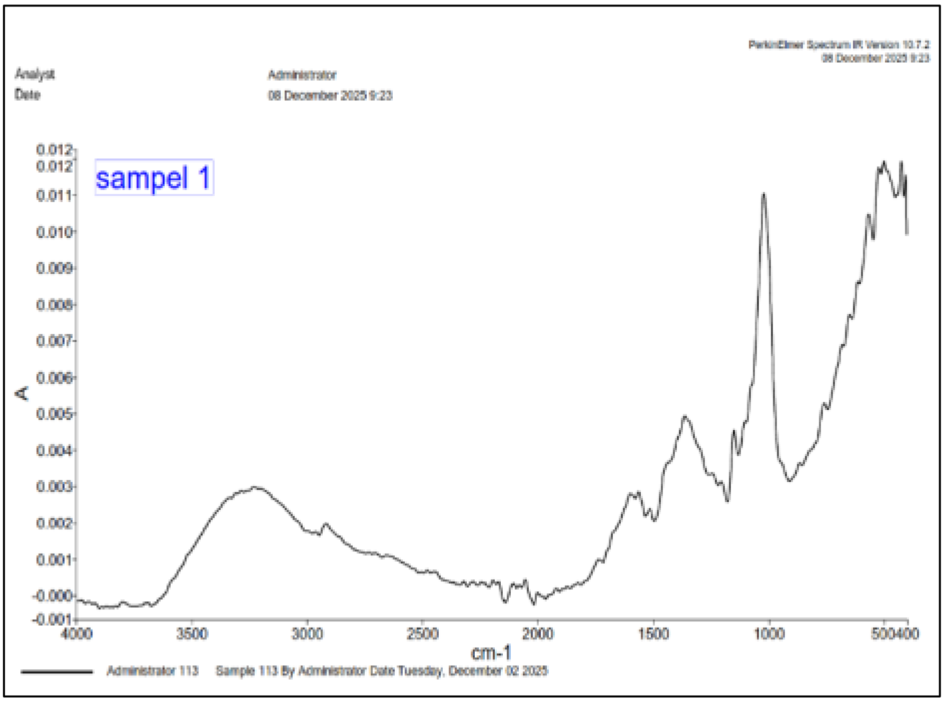


Figure 1 Results of Fourier Transform Infrared Spectroscopy (FTIR)

Based on Figure 1, the results of the *Fourier Transform Infrared Spectroscopy* (FTIR) analysis on all meatball samples and the analyzed microplastic physical samples yielded FTIR spectra showing characteristic absorption patterns of synthetic polymers. All spectra exhibited dominant absorption bands in the wavenumber region of 3000–2800 cm^{-1}, indicating stretching vibrations of aliphatic C–H groups ($-CH_2$ and $-CH_3$). These absorption bands are a key characteristic of hydrocarbon-based plastics, particularly the polyolefin group. In addition, all samples also showed absorption bands around 1470–1450 cm^{-1}, corresponding to bending (bending/scissoring) vibrations of $-CH_2$ groups, and bands in the region of 1380–1370 cm^{-1}, related to bending vibrations of $-CH_3$ groups. The presence of these bands indicates that the identified microplastics have a longsaturated carbon chain structure. FTIR analysis of all samples showed that the dominant type of microplastic polymer in meatball balls is Polyethylene (PE), with a small possibility of a mixture of Polypropylene (PP).

4 Discussion

4.1 Microplastic Concentration in Meatballs

The results of this study indicate that all meatball samples analyzed contained microplastics, with concentrations ranging from 4.00 to 9.00 mg/kg. These findings confirm that ready-to-eat foods have the potential to serve as a significant pathway for human exposure to microplastics. Previous studies have reported that microplastics have been detected in various types of food, including processed products and ready-to-eat foods, with contamination levels varying depending on production processes and environmental conditions [3][4].

The variation in microplastic concentrations among meatball samples is likely influenced by differences in processing practices, the frequency of contact with plastic utensils, as well as exposure to ambient air during production and sales.

Mechanical exposure such as grinding and mixing of ingredients is known to accelerate the release of microplastic particles from plastic surfaces into the food matrix [6]. In addition, the open environment where ready-to-eat foods are sold also contributes to the deposition of microplastics from the air [5].

4.2 Characteristics of Microplastics Based on Shape and Size

Based on the results of morphological identification, microplastics in the form of fragments are the most dominant type compared to fibers. The dominance of fragments indicates that the main source of microplastics is likely from the degradation of hard plastics, such as containers, cutting boards, and plastic processing equipment. Fragments generally form as a result of physical abrasion, thermal degradation, and repeated use of plastic equipment in food processing [7].

The presence of microplastics in fiber form also indicates a contribution from air contamination, which is often associated with synthetic fibers from clothing, rags, or the environment around the production area. Previous studies have reported that microplastic fibers are the dominant form originating from airborne deposition on ready-to-eat foods produced in open or semi-open spaces [5].

The size of microplastics identified in this study ranged from 1.90–3.80 mm, which falls into the category of large microplastics. Nonetheless, large microplastics have the potential to further fragment into smaller particles during digestion, thereby increasing the likelihood of interaction with biological tissues [10].

4.3 Types of Microplastic Polymers and Sources of Contamination

FTIR analysis shows that polyethylene (PE) is the most dominant type of polymer found, with a small possibility of polypropylene (PP) being present. These two types of polymers are the most widely used plastic materials in food packaging, plastic bags, and kitchen utensils due to their lightweight, flexible nature, and resistance to heat and chemicals [11].

The dominance of PE and PP polymers in meatballs indicates that microplastic contamination most likely originates from direct contact with plastic packaging and processing equipment. This finding is consistent with various studies reporting that PE and PP are the most frequently detected polymers in processed foods and ready-to-eat foods [8][12].

4.4 Implications for Food Security and Consumer Health

The presence of microplastics in meatballs has important implications for food safety, although to date there are no regulatory thresholds specifically governing the content of microplastics in food. Microplastics are known to act as vectors for chemical additives, heavy metals, and pathogenic microorganisms, which can potentially be released and accumulate in the human body after ingestion [9].

Recent toxicological studies have shown that exposure to microplastics through food consumption can trigger oxidative stress, inflammatory responses, as well as disturbances in metabolic and immune functions, especially with long-term exposure [2][10]. Therefore, the results of this study emphasize the importance of improving hygienic practices, reducing plastic use in food processing, and stricter monitoring of ready-to-eat foods to minimize the risk of microplastic exposure for consumers.

5 Conclusion

This study shows that all meatball samples sold in Kambu District, Kendari City, were contaminated with microplastics at concentrations ranging from 4.00–9.00 mg/kg. The microplastics were predominantly in fragment form, with an average size of 2.99 mm, and the main polymer type was polyethylene (PE). These findings indicate that ready-to-eat foods have the potential to be a route of human exposure to microplastics, highlighting the need for enhanced food safety monitoring and the implementation of more hygienic processing practices to minimize the risk of contamination.

Compliance with ethical standards

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Disclosure of conflict of interest

There is no conflict of interest in this research

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