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Determination and Quantification of Microplastics in Cooking Oil Sold in Indonesia

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Abstract |Many studies on microplastics (MPs) in food have been done, but not much has been done on cooking freely available oil samples, especially in Indonesia. This study aims to determine and quantify the presence of MPs in various types of commercial cooking oil in Indonesia to support the achievement of the United Nations Sustainable Development Goals (SDGs), especially Goal 3: Good health and well-being, and Goal 12: Responsible consumption and production. This study uses a quantitative descriptive approach by sampling cooking oil from seven categories: palm cooking oil (packaged and bulk), imported cooking oil (canola, corn, and soybean), and coconut oils. MPs extraction is done by dissolving oil with organic solvents, filtration, and identification of MPs particles using a stereoscope light microscope. Further characterization was carried out based on the shape and color of the MPs found. The results revealed that 33 samples were contaminated with MPs, with bulk cooking oil containing the highest number of particles (19), while coconut oil had the lowest (two particles). The dominant forms of MPs were fibers and fragments, while the dominant colors were black, blue, and transparent. MPs have been detected in all types of cooking oil tested, indicating potential exposure through regular consumption. This research has an impact on increasing awareness of the risk of MPs contamination in food products and the importance of quality control in the cooking oil industry.

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Introduction

Cooking oil is a staple food widely consumed by the Indonesian people (Rahmayanti *et al*., 2025; Setyobudi *et al*., 2024a). However, growing environmental plastic pollution has raised increasing concerns about the presence of MPs in the food chain. (Waring *et al*., 2018). MPs have been reported to contaminate various food commodities in Indonesia, such as cane sugar (Sincihu *et al*., 2023), compost (Iswahyudi *et al*., 2023; 2024b), cooking oil (Setyobudi *et al*., 2024a), paddy (Iswahyudi *et al*., 2024a), potato (Setyobudi *et al*., 2024b, 2024c), salt (Putri *et al*., 2023), seafood (Ekalaturrahmah *et al*., 2025), water (Garfansa *et al*., 2024a; Setyobudi *et al*. 2024b), red palm oil (Saati *et al*., 2025), and goat milk (Wahyudi *et al*., 2025).. Later, attention began to be focused on the possibility of MPs contamination in fatty foods such as cooking oil, mainly due to the lipophilic nature of some types of plastics (Yuan and Xu, 2023). These lipophilic properties allow some types of MPs particularly those derived from polymers such as polyethylene (PE), polypropylene (PP), and polystyrene (PS), to partially dissolve or be adsorbed in oily media (Skrzypek *et al*., 2024). In addition, the process of production, storage, and distribution of cooking oil that involves contact with plastic materials whether in the form of containers, hoses, or packaging also has the potential to become a contamination route (Jahirul *et al*., 2022). A review of the manuscripts summarized by Hahladakis *et al*. (2018) explains the migration of MPs in edible oil, especially by plastic synthesis additives.

This situation is further worsened by the absence of specific regulations in Indonesia regarding acceptable thresholds for MPs contamination in food (Rauf *et al*., 2024; Setyobudi *et al*., 2024a and 2024b). Without valid data on the presence and concentration of MPs in cooking oil, people are vulnerable to potential exposure to these persistent and toxic contaminants (Hahladakis *et al*. 2018; Ziani *et al*., 2023).

Given that MPs can act as vectors for harmful chemical compounds such as heavy metals, pesticides, and persistent organic compounds, their presence in cooking oil can increase the potential for toxicological hazards (Hahladakis *et al*. 2018; Kinigopoulou *et al*., 2022). In addition, the accumulation of MPs in the human body through daily consumption of cooking oil can trigger inflammatory responses, oxidative stress, and metabolic system disorders (Garfansa *et al*., 2024a; Hermayanti *et al*., 2024; Winiarska *et al*., 2024). Cooking oil can potentially be contaminated with MPs from raw materials, production processes, packaging, and distribution (Setyobudi *et al*., 2024a). However, scientific data related to the existence and level of MPs contamination in cooking oil in Indonesia is still minimal (Setyobudi *et al*., 2024a), especially in palm cooking oil. Meanwhile, Battaglini *et al*. (2024) and Guo *et al*. (2023) reported MPs contamination in non-palm vegetable oils. Therefore, this study is essential to be conducted as an initial effort to understand the potential risk of MPs exposure through cooking oil consumption (Battaglini *et al*., 2024; Guo *et al*., 2023; Ryosa *et al*., 2017; Sari *et al*., 2014; Setyobudi *et al*., 2024a). This lack of data is an obstacle in assessing the extent of public health risks due to the consumption of cooking oil contaminated with MPs, both in the short and long term (Cahyono *et al*., 2019; Dhewanta, 2017; Encephala, 2018; Garfansa *et al*., 2024b; Hermayanti *et al*., 2024; Mamun *et al*., 2023; Yustinasari *et al*., 2019).

A study by Senathirajah *et al*. (2021) showed humans' average intake of MPs from various sources. Meanwhile, detection methods such as FTIR and Raman spectroscopy have been used extensively to identify MPs in complex matrices, including oils and fats (Iswahyudi *et al*., 2024b; Setyobudi *et al*., 2024a). The presence of MPs in agricultural products such as potatoes indicates that contamination can occur from the cultivation stage due to contaminated irrigation water or organic fertilizers (Setyobudi *et al*., 2024c). Meanwhile, the findings of MPs in compost and soil confirm that even recycled organic matter is not immune to exposure to plastic particles (Iswahyudi *et al*., 2023). The discovery of MPs in cooking oil, although still limited, indicates that processed food products consumed daily can also potentially be a medium of MPs exposure for humans (Sanchez *et al*., 2022). This fact further strengthens the urgency to systematically monitor MPs contamination in various food products, to understand the routes of contamination and its impact on human health (Ezeh and Agu, 2024).

This study aims to determine the presence and measure the level of MPs contamination in cooking oil sold in Indonesia and identify the number, shape, and color of MPs contained in it. In addition, this study will also analyze differences in MPs content based on the type of brand category of cooking oil products in the market. By conducting systematic and scientific quantification, this study is expected to provide accurate and accountable initial data on the potential for MPs contamination in one of the main food ingredients of the Indonesian people. Significantly, the results of this study will be an essential contribution to the development of science in food safety and environmental toxicology. The data obtained can be used to formulate policies to monitor the quality of cooking oil and protect consumers from exposure to microplastics. In addition, this study can encourage food producers to re-evaluate production and packaging practices that risk causing plastic contamination and increase public awareness of the importance of choosing food products that are safe from environmental pollution. Also, this research supports the achievement of the United Nations Sustainable Development Goals (SDGs), especially the 3rd Goal: Good health and well-being, and the 12th Goal: Responsible consumption and production (United Nations, 2025).

Materials and Methods

Material

Chemicals for degradation were used in the Fenton process. *i.e.,* H_2O_2 30 % and Fe_2SO_4 $7H_2O$, while for density separation, a 30 % NaCl solution was used (all ingredients are technical chemicals), and distilled water was purchased at the Nurra Gemilang shop, Malang (S 7°56'31.0524" and E 112°36'5.238"). A 300 mesh linen cloth (disposable) for filtration was purchased online at Sumber Flitech Mandiri, Jakarta (S 6°8'35.916" and E 106°48'55.9224") via Shopee. This study also used glass equipment, comprising glass beakers, flasks, pipettes, bottles, vials, glass stirrers, and petri dishes. Aluminum foil for covering glassware was used. Some sticker paper was also desired for sample indication. This study used research lab., Faculty of Medical, University of Muhammadiyah Malang, Campus II for preparation (S 7°57'25.7868" and E112°36'52.4808"), and optics lab. for MPs identification in the Department of Biology, Faculty of Science and Technology, State Islamic University of Maulana Malik Ibrahim, Malang, Campus I (S 7°57'2.3328" and E 112°36'24.5592").

Sample

Thirty-three cooking oil samples (1st brand, 2nd brand, 3rd brand, small oil refinery, coconut oil, and imported cooking oil) were bought from several grocery stores in Malang (East Java, Indonesia) and online/marketplace. In contrast, bulk cooking oil was bought at four traditional markets in Malang (Oro-oro Dowo, Mergan, Kasin, and Bareng). The commercial brands are not shown for privacy reasons, validity, and subjectivity.

The selection of cooking oil samples was based on two sources, namely i) "top brand award 2023 and 2024" and ii) a statement by the Executive Director of Indonesian Vegetable Oil Industry Association (*Gabungan Industri Minyak Nabati Indonesia* - GIMNI) that there are five large companies out of 75 cooking oil manufacturers that dominate the Indonesian market, namely PT Indofood Sukses Makmur Tbk, Wilmar Group, PT Sinarmas Agribusiness and Food, PT Bina Karya Prima, and Musim Mas Group.

Sampling method

In detail, the method used refers to Yona *et al.* (2021), modified by Setyobudi *et al.* (2024a). The MP's analysis method is generally carried out in sample preparation, organic material degradation, density separation, sample sorting, and observation. The preparation used 20 mL of cooking oil placed in a glass bottle (300 mL), plus 2 × 10 mL of 30 % H_2O_2 (and 5 mL of Fe_2SO_4 $7H_2O$. Incubation was carried out for 12 h procedure for water bath, filtering, and washing with 30 % NaCl solution after incubation. Sample analysis was duplicated (Damat *et al.*, 2021) to calculate the mean and standard deviation.

MPs Identification

The shape, color, and number of the MPs were identified using a stereo light microscope with 3.75× to 540× magnification (Nikon SMZ 1500, with digital camera DXM 1200C, connected to Hewlett-Packard TV, 12 inch). The MPs particles found were documented, and quantitative and qualitative observations were carried out. Quantitative observations include the number of particles (fibers, filaments, fragments, granules, etc.) (Iswahyudi *et al.*, 2024b).

Results and Discussion

Number of MPs

Based on Figure 1, the number of MPs in the cooking oil studied varies depending on the type and source of the product. Bulk cooking oil has the highest number of MPs with 19 particles, followed by products from small oil refineries with 18 MPs particles, and 3rd brand with 15 MPs particles. Meanwhile, the 1st and 2nd brands contributed nine and seven MPs particles, respectively. Imported cooking oil (Import Co.: Canola, corn, and soyabean) also has seven particles of MPs, while coconut oil (coconut oil) is recorded as the least researched, namely only two particles of

MPs.

This distribution of MPs suggests that more attention is focused on bulk oils and products from small refineries, which are generally associated with simpler production and packaging processes and higher possible exposure to MPs. On the other hand, while important, large commercial brands and imported products tend to have fewer MPs. This may reflect the initial hypothesis that the potential for MPs contamination may be more significant in products that are packaged and manufactured to lower quality control standards. This approach allows researchers to obtain a more comprehensive picture of the variation in the potential for MPs contamination in various cooking oils circulating in the Indonesian market.

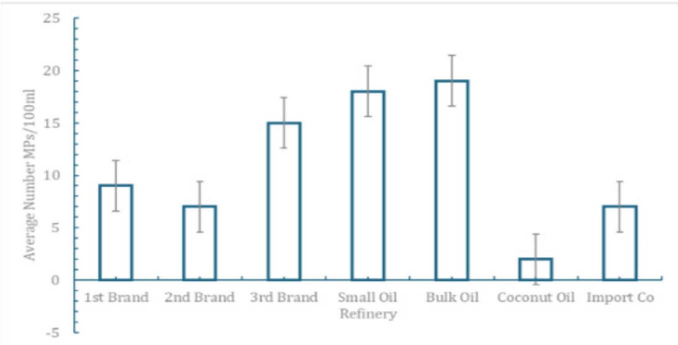

Figure 1: *Number of microplastics in cooking oil*

The findings of MPs in cooking oil studies align with the results of international studies that show that MPs can contaminate various types of food, including oily products. One of the early studies that raised this issue was a study by Setyobudi *et al.* (2024a), which reported the presence of MPs particles in palm oils sold in Indonesia and vegetable oil (Battaglini *et al.*, 2024; Guo *et al.*, 2023). They found that MPs can get into vegetable oil during production and packaging, especially when using plastic containers or utensils. However, Setyobudi *et al.* (2024a) suspect that the source of MPs is likely to have occurred in oil palm cultivation, because the authors of this team found MPs contamination in tissue culture seedling acclimation (Setyobudi and Anwar, 2024).

In addition, other studies also revealed the presence of MPs in household consumption products, including cooking oil, which they considered a potential vector of oral exposure to microplastics. Furthermore, it emphasizes that oily mediums such as cooking oil have a high potential to attract and retain microplastics due to the lipophilic properties of some plastic polymers such as polypropylene (PP) and polyethylene (PE), which are commonly used in food packaging (Hahladakis *et al.* 2018).

These studies reinforce the urgency to evaluate food safety in terms of non-biological physical contamination such as MPs (Pironti *et al.*, 2021), which have been more often studied in cane sugar (Sincihu *et al.*, 2023), salt (Putri *et al.*, 2023), seafood (Ekalaturrahmah *et al.*, 2025), and processed potato products (Setyobudi *et al.*, 2024b). The findings in the study also support the global view that MPs have become a cross-commodity threat that is not only limited to the aquatic environment but also includes oily food products that are widely consumed in developing countries (Hahladakis *et al.* 2018; Zhao and You, 2024).

Shape

Based on Figure 2, the most dominant forms of MPs found in different types of cooking oil are fibers and fragments, while other forms, such as granules, films, and filaments, are found in lower proportions and vary depending on the type of product. Generally, fiber is the most common form detected in almost all samples, with the highest proportion found in oil from small oil refineries (53 %) and the lowest in bulk oil (38 %). Fiber is the only form of MPs found in all product categories, including coconut oil (50 %), which does not contain fragments, granules, or filaments.

Fragments are also the second dominant form, with the highest percentage in bulk oil (50 %) and relatively high in 3rd brand (40 %) and small oil refineries (37 %). This shape indicates the degradation process of fragmented plastics before or during the oil processing process. Granules are found in limited quantities, with the highest proportion being 25 % in 1st brand and only 3 % in bulk oil. It indicates possible contamination from plastic packaging materials or industrial residues. The film appears in small quantities and only on 2nd brand, 3rd brand, bulk oil, and coconut oil in coconut oil, it reaches 50 %, indicating direct exposure to thin plastic packaging materials such as plastic wrapping.

Meanwhile, filaments are rare, appearing only in small oil refineries (5 %), bulk oil (6 %), and import co. (14 %). Filaments are generally derived from textile materials or plastic brushes, and their presence can signal secondary contamination from the processing or packaging environment. These findings show that microplastics in cooking oil vary quantitatively and morphologically. These shapes can potentially affect the nature of microplastics' interactions with the human body and indicate different sources and pathways of contamination.

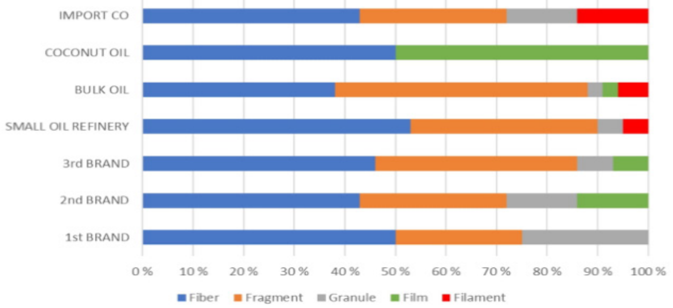

Figure 2: *Shape of microplastics in cooking oil*

The findings of MPs in cooking oil in this study, especially the dominance of fibers and fragments, align with the results of previous research in various food and environmental media. The fiber form is known to be one of the most common forms of MPs found, mainly because it comes from synthetic fibers of clothing, plastic ropes, nets, and other textiles that are easily released into the environment during production, processing, and distribution.

A study by Prata *et al.* (2020) shows that fiber is the most commonly detected form of MPs in drinking water and ambient air, which allows cross-contamination to foods such as cooking oil during processing or packaging. Fiber is also reported to be the dominant form in seafood and salt, as shown by the study of Putri *et al.* (2023). Meanwhile, fragments are a form of MPs resulting from hard plastic fragments and are often associated with mechanical degradation or photodegradation of plastic packaging or equipment. A study by Battaglini *et al.* (2024) that examined the presence of MPs in vegetable oils in Spain also showed fragments in plastic products, suggesting that the packaging process is a potential contamination pathway.

The findings of lower granule, film, and filament shapes also correspond to a general trend in the literature. Granules are usually primary MPs (such as microbeads) or derived from plastic resins, while films and filaments result from the degradation of thin plastics and textile materials (Mulyasari *et al.*, 2023; Zhang *et al.*, 2025). In cooking oil, the film is most likely from flexible plastic packaging, while the filament can come from a cleaning brush, filter, or other environmental source (Azevedo *et al.*, 2022). Overall, the results of this study confirm that cooking oil can be a medium that is susceptible to MPs contamination from various forms and sources, as has been identified in international studies.

Color

Based on Figure 3 on MPs color data found in various types of cooking oil in Indonesia, the dominant color that was most detected was black. Cooking oil from the import co has the highest percentage of black MPs at 86 %, followed by bulk oil (73 %) and small oil refinery (60 %). This black color is most likely derived from plastic particles that have undergone thermal degradation or photodegradation, as well as from recycled plastic components such as tires, pipes, or dark-colored packaging that are widely used in industry. In addition to black, blue, and red, other colors were found in significant numbers in some samples. For example, coconut oil shows a blue and transparent color composition of 33 % each, while 3rd brand contains 40 % red MPs. Blue and red are generally related to plastics in food packaging, household products, or synthetic textile materials.

Transparent colors are also relatively standard, such as in coconut oil (33 %) and 1st brand (20 %), indicating the presence of plastics such as polyethylene or polypropylene, often used as coatings in food packaging. Other colors, such as gray, brown, yellow, purple, and green, are found in small proportions, each sporadically dispersed on several types of oil. For example, a small oil refinery has a variable color distribution, with 5 % each. This diversity of colors shows that MPs that pollute cooking oil can come from various sources and types of plastic, ranging from household waste, industrial processes, to packaging. Color variations also reflect the degree of degradation and complexity of the MPs' contamination chain that enters food products.

The findings of MPs colors in cooking oil in Indonesia, with a dominance of black, blue, and transparent colors, align with previous research in various food and environmental media. The color of microplastics can indicate the origin or type of plastic and its potential toxicological hazards. Research by Guo *et al.* (2023) in China found that MPs in commercial vegetable oils are dominated by small sized fragments, with the primary colors being black and blue. This study shows that the production and packaging process can be a source of MPs contamination in cooking oil.

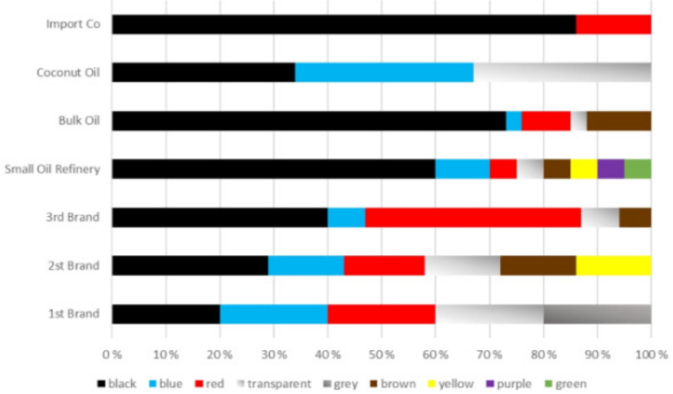

Figure 3: *Color microplastics in cooking oil*

In addition, research by Battaglini *et al.* (2024) in Spain detected MPs in PET bottled cooking oil, with particles reaching 5.80×10^5 L^{-1}. Most particles are small (< 10 μm) and are composed of polymers such as polyethylene and polypropylene, which are often used in food packaging. Research in the Persian Gulf by Gholizadeh *et al.* (2023) also reported that the most common MPs colors found in marine organisms were black (52.83 %), followed by blue (22.64 %) and transparent (15.09 %). It shows that black and blue are the dominant colors of MPs in the marine environment, which can enter the human food chain through seafood consumption. The predominance of black and blue colors indicates that the source of MPs contamination can come from the production process, packaging, and the surrounding environment (Setyobudi *et al.*, 2024a; Xu *et al.*, 2020).

The findings in this research support Setyobudi *et al.* (2024a), namely that bulk cooking oil is most heavily contaminated with MPs. Likewise, the findings show the dominance of black fiber shapes in palm cooking oil. Setyobudi *et al.* (2024a) proposed that car tire debris is a source of MPs pollution. This debris floats from the wind to oil palm plantations, sticks to oil palm leaves, and/or car tire debris falls with rainwater and pollutes oil palm plants and soil. Furthermore, this debris is carried to crude palm oil (CPO) as the basic ingredient of palm cooking oil.

As a note, besides car tire debris carried by wind from urban areas. Car activity in oil palm plantations is relatively high to serve oil palm plantation maintenance and harvest transportation. Evidence of rainwater and irrigation water dominated by black fibers has also been reported by Garfanca *et al.* (2024a) and Setyobudi *et al.* (2024b). Research by Utami *et al.* (2023) supports this tire debris hypothesis.

Conclusions and Recommendations

This study aims to determine and quantify the presence of MPs in various cooking oils sold in Indonesia. The results showed that MPs were found in all cooking oil samples analyzed, with the highest contamination in bulk oil (19 particles) and the lowest in coconut oil (two particles). The dominant forms of MPs are fibers and fragments, while other forms, such as granules, films, and filaments, are also detected in varying amounts. In terms of color, the most common microplastics found are black, blue, and transparent, with the dominance of black, especially in imported products and bulk oil. This study is critical because it provides preliminary evidence on the potential exposure to MPs through cooking oil consumption in Indonesia and emphasizes the need for stricter food quality monitoring. Further research is recommended to trace the origin of MPs contamination along the cooking oil supply chain and examine its toxicological impact on human health.

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Novelty Statement

This research has conducted MPs pollution tests on 28 brands of palm cooking oil and compared them with two brands of coconut oil and three imported cooking oils (canola, corn, and soybean) sold in the Indonesian market. The authors have tracked Google

Scholar until May 2025 and found no research on MPs pollution in cooking oil sold in the Indonesian market. The authors only found research by Setyobudi *et al*. (2024a), a preliminary study (9 brands of palm cooking oil, two brands of coconut oil, and one brand of imported canola cooking oil).

Guo *et al*. (2023) conducted a study on four types of vegetable oil products from the United States, namely olive oil, canola oil, sunflower oil, and coconut oil, while Battaglini *et al*. (2024) conducted it on vegetable oils from Italy and Spain, namely virgin olive oil, olive oil, sunflower oil, and mixed oils of various seeds. Based on the tracking above, the author states that the research on 33 cooking oil brands sold in Indonesia is a novelty, especially the observation of MPs pollution in palm cooking oil.

Authors Contribution

Damat Damat: Research supervision, grant funds, and manuscript review.
Roy Hendroko Setyobudi: Conceptualized and designed the study, elaborated the intellectual content, supervised and served as research coordinator in the laboratory, performed literature search, manuscript review, and manuscript revision.
Iswahyudi Iswahyudi: Performed literature search and manuscript preparation.
Yudhiakuari Sincihu: Manuscript review, and guarantor of microplastic analysis.
Anik Anekawati: Statistical analysis.
Hanif Alamudin Manshur, Satriyo Krido Wahono, Muslih Anwar, Suherman Suherman and Marchel Putra Garfansa: Manuscript review.
Resky Adelia Saputri: Visualization the graph.
Siti Alfiatul Amani: Administration.

Generative AI and AI-assisted technology statement
The authors stated that they didn't use generative AI and AI-assisted technology in preparing this manuscript

Conflict of interest
The authors confirmed that they have no conflict.

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