# CHARACTERISTICS AND ABUNDANCE OF MICROPLASTICS IN THE INTESTINES OF TIGER SHRIMP (*Penaeus monodon*) AT THE LARANGAN MARKET IN SIDOARJO

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**ABSTRACT**

Microplastic pollution has become an increasing environmental concern in aquatic ecosystems and is frequently detected in seafood consumed by humans. Several studies have documented microplastics in shrimp, but many rely mainly on visual identification or a single analytical method. As a result, detailed information on microplastic characteristics is still limited, particularly in shrimp sold for human consumption. This study investigated the characteristics and abundance of microplastics in the intestines of tiger shrimp (*Penaeus monodon*) obtained from Larangan Market, Sidoarjo, and considered their possible relevance to human exposure through seafood consumption. Twenty shrimp samples were analyzed, consisting of 10 males and 10 females with body lengths of 13–15 cm. Intestinal tissues were digested using 10% KOH at 60 °C for 24 hours and filtered using Whatman grade 42 filter paper (2.5 µm). Microplastics were identified according to their shape, size, and color using a stereo microscope equipped with Optilab imaging. Polymer composition was determined using Fourier Transform Infrared (FTIR) spectroscopy, while surface morphology was examined using Scanning Electron Microscopy (SEM). The use of these combined techniques allowed a more thorough identification of microplastics than approaches relying on a single method. Microplastics were detected in all shrimp samples, with an average abundance of 16.10 ± 3.75 particles per individual in males and 18.40 ± 6.60 particles per individual in females. The particles were mainly blue fragments measuring 10–50 µm, and FTIR analysis indicated nylon (polyamide, PA) as the dominant polymer type. SEM images also showed rough and irregular particle surfaces, suggesting that the detected particles were secondary microplastics produced by the fragmentation of larger plastic debris. These results provide additional evidence of microplastic contamination in *P. monodon* sold for human consumption in Sidoarjo and emphasize the importance of using multiple analytical techniques to better understand microplastic sources and their possible transfer to humans through seafood.

**Keyword:** FTIR, Intestine, Microplastics, *Penaeus monodon*, SEM

## Introduction

The city of Sidoarjo is the capital of Sidoarjo Regency, located in East Java and surrounded by mountains, including Mount Arjuno, Mount Welirang, and Mount Penanggungan [1]. Plastic pollution in Sidoarjo Regency has become a significant environmental issue, producing a total of 1,086 tons of waste tons/day, making Sidoarjo Regency the fourth largest waste producer in East Java according to data from the National Waste Management Information System (SIPSN) in 2020, and producing 1,860.24 microplastics in the aquatic environment [2]. Microplastics are plastic particles measuring <5 mm and are divided into primary microplastics, originating from products such as cosmetics and detergents, and secondary microplastics originating from the degradation of plastic waste. Microplastics consumed by shrimp can be absorbed and cause toxic transfer to humans [3]. The effects include biological damage, oxidative stress, inflammation, metabolic disorders, immunity, reproduction, neurotoxicity, and an increased risk of cancer due to its carcinogenic properties [4]. Shrimp are invertebrates that live in various waters such as rivers, seas, and lakes. As opportunistic omnivores, including tiger shrimp (*Penaeus monodon*), shrimp can adapt to a variety of food sources at the bottom of the water [5]. Shrimp play an important role in the ecosystem by consuming organic debris and converting it into nutrients for other organisms. However, their feeding habits make shrimp susceptible to ingesting microplastics, which can accumulate in their intestines and disrupt their metabolism [3]. Additionally, microplastics also function as vectors for pollutants such as persistent organic compounds and heavy metals, which can be transferred to humans through the food chain [6]. Research [7] found microplastics measuring <250 µm to 1–5 mm in the form of fibers, particles, and fragments in black, white, green, blue, and red found in tiger shrimp (*P. monodon*) from the Bay of Bengal. Consumption of shrimp without cleaning the internal organs risks increasing the transfer of microplastics to humans. This is reinforced by research [6] which shows that microplastics accumulate most in the digestive tract (intestines) of shrimp, and more so in farmed shrimp. In addition, research by [8] also proves that shrimp sold in supermarkets contain microplastics [8].

# Methodology

**Study Area and Sampling**

This research was conducted in April 2025 to June 2025. Sampling was carried out at Larangan Market in Sidoarjo, and sample preparation was conducted at the Ecology Laboratory, Department of Biology, Faculty of Science and Data Analytics, Institut Teknologi Sepuluh Nopember Surabaya. The SEM analysis will be conducted at the Energy and Environment Laboratory, Institut Teknologi Sepuluh Nopember. Meanwhile, the FTIR analysis will be conducted at the Department of Industrial Chemical Engineering, Vocational Faculty, Institut Teknologi Sepuluh Nopember Surabaya.

**Species Selection Justification**

Tiger shrimp (*P. monodon*) was selected as the bioindicator for this study due to its significant economic value as a primary fishery commodity in Sidoarjo [9]. From an ecological perspective, *P. monodon* is a benthic scavenger that primarily feeds on organic matter in the sediment [10]. Since microplastics (especially fibers and fragments) tend to settle and accumulate in the seafloor sediments, this species has a high probability of ingesting these pollutants [11]. Therefore, analyzing *P. monodon* provides a representative assessment of microplastic contamination in the local marine food web and potential risks to human consumers [12].

**Sample Preparation and Extraction**

***Collection samples***

Sampling of tiger shrimp (*P. monodon*) was conducted randomly at Larangan Market in Sidoarjo based on the desired size, which was 13–15 cm. A total of 20 individuals consisting of 10 males and 10 females were selected with minimal differences in size [13]. The samples were then wrapped in aluminum foil and stored in a cool box at a temperature below 5ºC to maintain freshness and prevent spoilage [14].

***Morphometric observations***

Morphometry is a method of measuring body parts of shrimp that is useful for distinguishing species or populations and showing adaptations to environmental changes. This study used morphometric parameters such as total length, cephalothorax, abdomen, caudal, and biomass to determine the characteristics of shrimp. Measurements were taken using a tape measure and digital scale [15].

***Microplastic analysis in the intestine***

The selected shrimp samples had their intestines removed by making an incision from the dorsal to the anal area using a sterile knife, then transferred to a petri dish using sterile tweezers for microplastic analysis [16]. The intestines of each individual were weighed to determine the biomass as a comparison for microplastic content. Extraction was carried out by mixing the intestines and a 10% KOH solution (1:10) in a flask, covered with aluminum foil, then heated in a 60ºC oven for 24 hours until the organic material dissolved. The resulting extraction solution was then filtered using Whatman grade 42 filter paper (2.5 µm pores) with a Buchner funnel and the results were used for microplastic analysis [17]. Physical identification of microplastics was performed through visual analysis to determine the shape, size, and color of microplastics in the intestine of giant tiger shrimpss (*P. monodon*) using a stereo microscope and Optilab. The dominant shapes were then further analyzed with Scanning Electron Microscopy (SEM) was specifically utilized to verify the surface textures and weathering patterns (such as cracks or pitting) that are characteristic of microplastics, providing a higher level of morphological certainty than optical microscopy alone [18]. Since SEM cannot display color, a stereo microscope with 4.5 x 10 magnification was used for color and shape analysis,

**Table 1.** Average Morphometric Measurement Results of Male and Female Tiger Shrimp (*P. monodon*)

| Sample Categories | Total Length (cm) | Chepalothorax Length (cm) | Abdominal Length (cm) | Caudal Length (cm) | Biomass (g) |
|---|---|---|---|---|---|
| Male *P. monodon* | 14,04 ± 0,63 | 5,44 ± 0,28 | 6,30 ± 0,33 | 2,29 ± 0,30 | 15,87 ± 2,02 |
| Female *P. monodon* | 13,95 ± 0,51 | 5,36 ± 0,28 | 6,34 ± 0,42 | 2,25 ± 0,29 | 16,73 ± 2,93 |

while documentation was assisted by Optilab software [19]. To calculate the abundance of microplastics, a calculation formula was used according to [20].

***Chemical composition analysis of the intestine***

The identification of the chemical characteristics of microplastics aims to determine the types of polymers in microplastics in the intestines of tiger shrimp (*P. monodon*), with samples taken from the results of physical identification. The analysis was performed using Fourier Transform Infra-Red (FTIR), which works by irradiating the sample with infrared light and then producing a reflection spectrum to identify the type of polymer based on functional groups and wave numbers [21]. The peak of the wave indicates the type of compound bond used to determine the type of microplastic polymer [22].

**Data Analysis**

This study is exploratory in nature with quantitative descriptive analysis to identify the visual characteristics of microplastics using SEM and stereo microscopes, as well as chemical characteristics using FTIR. The percentage and standard deviation of each characteristic were calculated using Microsoft Excel [14].

## Result and Discussion

**Morphometry of Tiger Shrimp (*Penaeus monodon*)**

Morphometric measurements were performed on 10 male and 10 female *Penaeus monodon* shrimp, with four parameters measured, total length, cephalothorax, abdomen, and caudal, as well as the biomass of each individual. The average results of morphometric measurements and biomass can be seen in Table 1 as follows.

Female shrimp generally grow faster and are larger than males due to their reproductive role. Their larger body size supports egg production and storage as well as embryo development, reflecting sexual dimorphism and providing reproductive advantages [9]. However, in this study, male shrimp were larger because the samples were obtained from the market, not from aquaculture, so they did not reflect natural conditions. To avoid bias in the microplastic analysis, samples with relatively homogeneous sizes between sexes were used.

Observation and measurement of biomass in the intestines was also carried out to determine the condition and mass of the intestines of each individual in each category. The average results of the intestinal mass can be seen in Table 2 below,

**Table 2.** Average Results of Biomass Measurements of Male and Female Tiger Shrimp (*P. monodon*) Intestines

| Sample Categories | Intestinal Biomass (g) |
|---|---|
| Male *P. monodon* | 0,011 ± 0,004 |
| Female *P. monodon* | 0,015 ± 0,013 |

Female *P. monodon* had heavier intestinal biomass than males, although without statistical significance. The standard deviation in females was also greater, indicating considerable variation in data between individuals. Some female shrimp have a much higher intestinal biomass than others, thereby increasing the mean and enlarging the standard deviation. A large standard deviation reflects a wide spread of data from the mean value [10].

**Analysis of Microplastic Physical Characteristics**

The analysis of the physical characteristics of microplastics consisted of observation of the shape, size, and color, as well as calculation of the abundance in the intestines of male and female tiger shrimp (*P. monodon*), each consisting of 10 individuals. The results of the calculation of microplastic abundance in the intestines of *P. monodon* from each category can be seen in Table 3.

Based on observations of 10 individuals of *P. monodon* of each sex, the total microplastics in the intestines of male shrimp were 161 particles (average 16.10 ± 3.75), while in females there were 184 particles (average 18.40 ± 6.60). This indicates that sex affects the accumulation of microplastics, due to physiological and feeding behavior differences [11].

**Table 3.** Abundance of Microplastics in Male and Female Tiger Shrimp (*P. monodon*)

| | Sample Categories | |
|---|---|---|
| | **Male *P. monodon*** | **Female *P. monodon*** |
| Total abundance of microplastics in 10 individuals (particles) | 161 | 184 |
| Average abundance of microplastics (particles/individuals) | 16,10 ± 3,75 | 18,40 ± 6,60 |

Faster allometric growth in female shrimp makes the abdomen, where the intestine is located, larger than in male shrimp [12]. The larger area and volume of the digestive tract in females has the potential to increase microplastic accumulation [11]. Conversely, male shrimp grow isometrically with a balanced body size, unlike females, which have a larger abdomen. Due to high energy requirements during reproduction, females eat more, resulting in higher microplastic accumulation in the abdomen [23].

Microplastic accumulation is higher in female shrimp due to different feeding behaviors, male shrimp are more active and aggressive in searching for food [24]. The high activity of male shrimp allows them to explore a wider area and select better food, thereby reducing the risk of ingesting microplastics from the water bottom [25]. Under certain conditions, male shrimp hide in the sand, reducing their exposure to microplastics, while female shrimp that forage in limited areas are more susceptible to ingesting microplastics because they are less selective [24]. Bottom sand that frequently deposits microplastics increases the risk of female shrimp ingesting microplastic particles while foraging on its surface [25].

***Shapes of Microplastic***

In the analysis of the physical characteristics of microplastics in terms of shape, which were obtained from the intestines of *P. monodon*, they were observed using a stereo microscope and Optilab viewer 2.2. The types of microplastic shapes observed can be seen in Figure 1.

Based on Figure 1, the microplastics found were in the form of fibers and fragments, the fibers resembled fine strands or pieces of fishing nets, often turning blue when exposed to UV light, and were commonly found on coastlines near fishing villages [26].

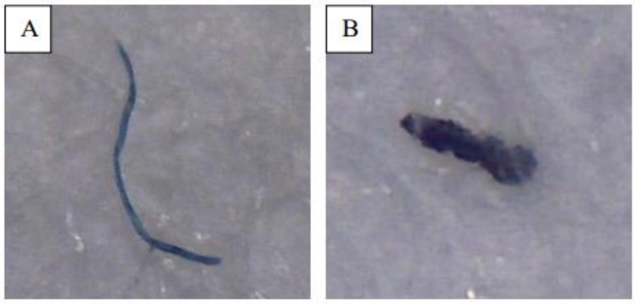


**Figure 1.** Microplastic Shapes Found in the Intestines of Tiger Shrimp (*P. monodon*), (A) Fiber (B) Fragment

The fibers are thin, elongated threads resembling synthetic fibers, originating from synthetic textiles, fishing lines, or nets, while the fragments are irregularly shaped with jagged edges and sharp corners like plastic shards [27]. The non-uniform shape indicates that the microplastics are the result of fragmentation, not natural. The hard and rigid texture indicates that the source material is strong and sufficiently resistant to physical degradation [28]. The graph of microplastic abundance based on the shape found in the intestine of *P. monodon* can be seen in Figure 2.

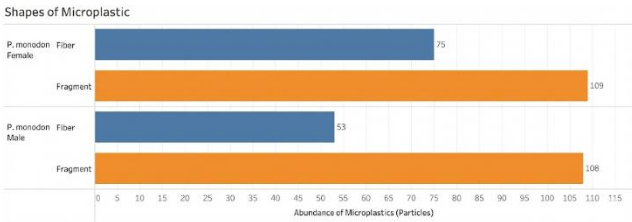


**Figure 2.** Abundance of Microplastics Based on Shape Found in the Intestines of Tiger Shrimp (*P. monodon*)

Microplastic fragments are mostly formed from the breakdown of macroplastics in the sea due to UV rays, waves, wind, and friction from sand and sediment. The use of seawater in shrimp farming is a pathway for microplastic fragments to enter the pond environment, increasing the risk of shrimp ingesting microplastics [29].

***Colors of Microplastic***

Microplastics obtained from the intestine of *P. monodon* were then analyzed physically based on their color using a stereo microscope and Optilab viewer 2.2. The various colors of microplastics observed can be seen in Figure 3.

Based on Figure 3, the colors of microplastics found vary, such as brown, red, yellow, green, blue, purple, black, gray, transparent, and white. These colors originate from the original pigments of the plastic and change due to weathering and photoaging caused by exposure to sunlight,

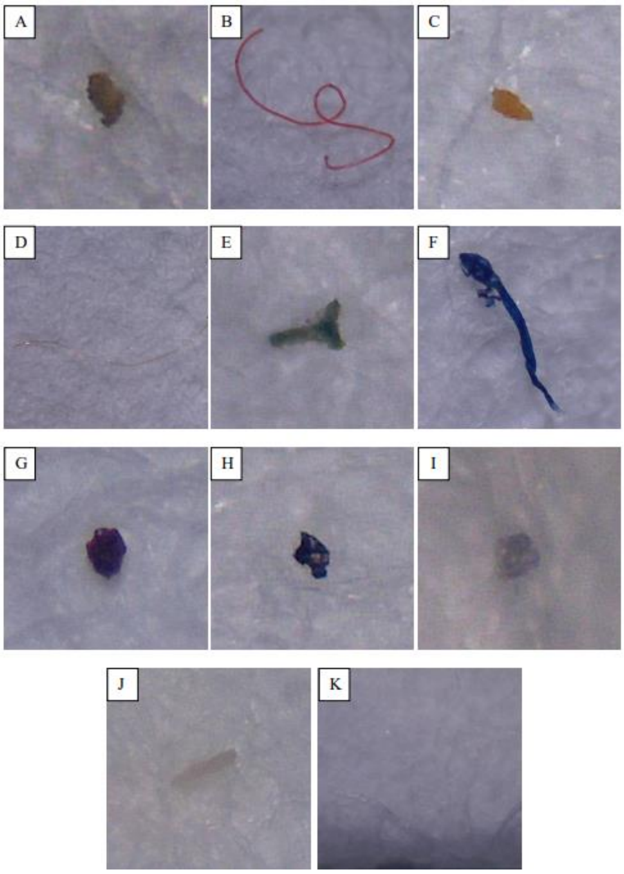


**Figure 3.** Microplastic Colors Found in the Intestines of Tiger Shrimp (*P. monodon*), (A) Brown (B) Red (C) Orange (D) Yellow (E) Green (F) Blue (G) Purple (H) Black (I) Gray (J) Transparent (K) White

which also causes fragmentation [30]. The graph of the abundance of microplastics based on color in the intestine of *P. monodon* can be seen in Figure 4.

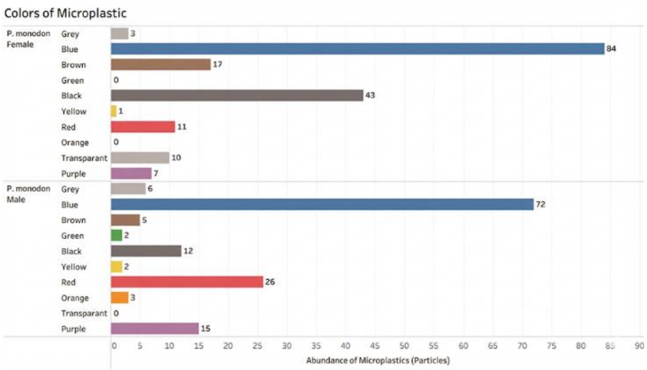


**Figure 4.** Abundance of Microplastics by Color Found in the Intestines of Tiger Shrimp (*P. monodon*)

Blue microplastics are most commonly found because they originate from fine fibers in household clothing that are released during washing and carried by water currents until they accumulate in waterways. In addition, blue microplastics also originate from plastic fishing equipment such as fishing lines and nets that are easily degraded, especially in aquaculture. Fragments from these tools enter the water and become a source of microplastics. After blue, black and red microplastics are commonly found, possibly because shrimp are attracted to colors similar to natural prey such as zooplankton. Black microplastics can also absorb pollutants, increasing their toxic potential when ingested [31].

***Size of Microplastic***

The microplastic size obtained from the intestine of *P. monodon* was observed using a stereo microscope and Optilab viewer 2.2. The observed size variation can be seen in Figure 5.

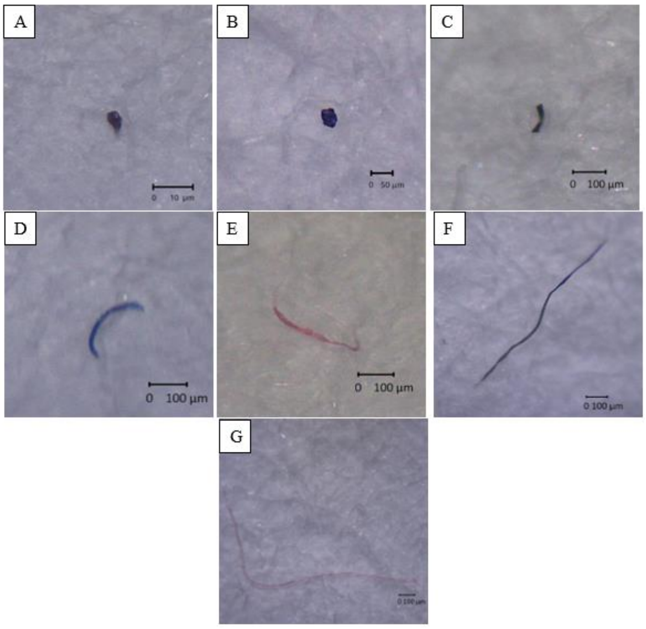


**Figure 5.** The Size of Microplastics Found in the Intestines of Tiger Shrimp (*P. monodon*), (A) 1–10 µm, (B) 10–50 µm, (C) 50–100 µm, (D) 100–250 µm, (E) 250–500 µm, (F) 500–1,000 µm, (G) > 1,000 µm

Based on observations, variations in microplastic size are caused by plastic degradation in the environment through erosion, solar radiation, and weathering, which trigger continuous fragmentation [32]. The graph showing the abundance of microplastics based on size found in *P. monodon* can be seen in Figure 6.

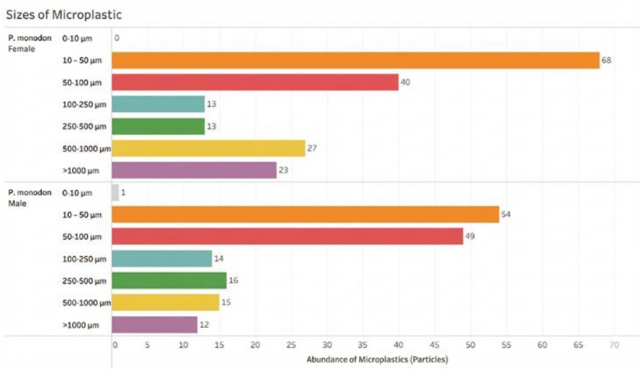

**Figure 6.** Abundance of Microplastics by Size Found in the Intestines of Tiger Shrimp (*P. monodon*)

Based on the graph in Figure 6, the dominant microplastic size in male and female *P. monodon* is 10–50 μm. This size is influenced by particle distribution and environmental degradation, not gender. Size variation results from the gradual degradation of large plastic waste into secondary microplastics. In addition, differences in microplastic size are influenced by physical distribution and transport in the water, large particles quickly settle at the bottom where shrimp feed, while small particles remain suspended and can be ingested during filtration or shrimp movement [33].

**Microplastic Bioaccumulation**

Omnivorous opportunistic shrimp eat detritus and plankton, making them susceptible to ingesting microplastics that are similar in size and difficult to distinguish from their food. Shrimp with compound eyes sensitive to blue-green colors tend to eat microplastics of similar colors, mistaking them for plankton or natural food [34]. The following is a graph of microplastic accumulation in the intestines of male and female tiger shrimp (*P. monodon*), each consisting of 10 individuals.

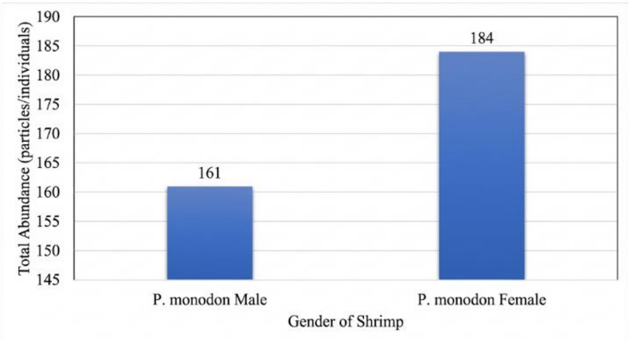


**Figure 7.** Graph of Total Microplastic Abundance (Particles/Individuals) in Both Categories of Shrimp Samples

Figure 7 shows that microplastic accumulation in female shrimp tends to be higher than in male shrimp [21]. Microplastics enter the shrimp's body through the mouth as food, causing microplastics to accumulate in the intestine [3]. Several previous studies have proven the accumulation of microplastics in giant tiger shrimp (*P. monodon*), such as [31], which detected microplastics in the intestine, with an average of 9.33 ± 0.82 particles/individual and a total of 33 particles from all samples. [35] also found microplastic accumulation in the exoskeleton and soft body of shrimp with an average of 30.75 ± 9.06 particles/individual. [36] added that although the intestine is the main location, accumulation in this organ is temporary because microplastics can be excreted [36]. Another study by [37] found that *P. monodon* accumulated microplastics in the intestine with an average of 0.74 ± 2 particles/individual. Meanwhile, [38] reported higher contamination levels, with an average of 7.7 ± 3.5 particles/individual. Microplastics with particles larger than 250 μm are more commonly found in the digestive tract than in body tissues [38]. The following table compares the abundance of microplastics from previous studies on tiger shrimp (*P. monodon*) [38].

There are significant differences between the results of this study and previous studies due to geographical factors (location, climate, type of water), levels of industrialization and urbanization, as well as the culture and habits of the community that affect microplastic pollution in each region [39]. Based on the results of the study, it is known that female shrimp have higher microplastic accumulation in the intestine than males, even though males may be larger in size. This is related to physiological and feeding behavior differences, where females experience allometric growth with dominant enlargement of the abdomen, where the intestine is located [22]. This larger abdomen increases the surface area and volume of the digestive tract, thereby increasing the potential for retention of higher amounts of microplastic particles [21]. In contrast, male shrimp exhibit isometric growth with proportional development of all body parts, so they do not experience significant enlargement of a particular part such as the abdomen [22]. The high microplastic content in *P. monodon*, especially in the intestine, has the potential to become a route of microplastic exposure for humans. The average abundance reached 16.10 ± 3.75 particles/individual in males and 18.40 ± 6.60 in females. Shrimp consumption can transfer microplastics to the human body and cause toxic effects such as oxidative stress, inflammation, metabolic disorders, and reproductive disorders [3]. In daily consumption, shrimp intestines are often not completely discarded, thereby increasing the risk of microplastic exposure. Ingested particles can attach to the digestive organs and trigger an immune response and lower the body's immune system [40].

**Analysis of Microplastic Chemical Characteristics**

Fourier Transform Infrared (FTIR) was the method used for microplastic chemical analysis in this study.

The microplastics used in this method included all forms found in the intestines of both categories of shrimp, namely male *P. monodon* and female *P. monodon*. The size used for fragment forms refers to the most dominant size of each category, namely 10–50 µm, while for fiber forms, the size used is 500–1000 µm. The results of microplastic polymer identification can be seen in Figure 8 in the form of the following FTIR spectra,

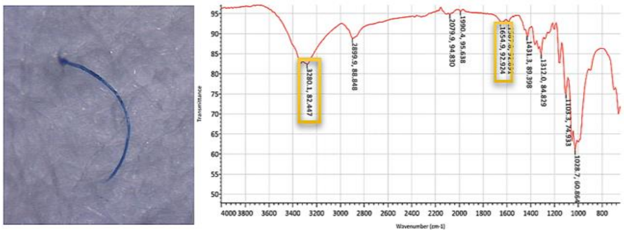

**Figure 8.** Results of Fourier Transform Infra-Red (FTIR) Analysis of Fiber Form in the Intestine of Tiger Shrimp (*P. monodon*)

Based on Figure 8, it is known that the results of fiber-shaped microplastic analysis in the intestine of tiger shrimp (*P. monodon*) detected nylon (PA) polymers. Nylon belongs to the polyamide synthetic polymer group, which has C=O and N–H functional groups, which are the main characteristics of the amide structure [41]. Identification was based on the position of specific wave numbers, such as N–H stretching around 3295 $cm^{-1}$ [42]. C=O stretching appears around 1650 $cm^{-1}$, N–H bending at 1530–1580 $cm^{-1}$, and aliphatic C–H stretching at 2925–2850 $cm^{-1}$ [41]. In shrimp farming, nylon is used in nets and ropes that are exposed to currents, friction, and sunlight, causing them to degrade and produce microplastics. These particles then enter the water column and can be ingested by shrimp [43].

**Analysis of Scanning Electron Microscopy (SEM)**

Scanning Electron Microscopy (SEM) was used to observe the surface structure of microplastic fragments measuring 10–50 µm, which were predominantly found in the intestines of male and female *P. monodon*, and to help identify their possible sources. The results of the microplastic surface analysis can be seen in Figure 9.

Based on Figure 9, it is known that the surface of microplastics shows irregular, rough, cracked, and eroded shapes, reflecting weathering in water due to abrasion, UV rays, and chemical factors. Observation with SEM effectively reveals this level of damage, although it does not show the polymer structure.

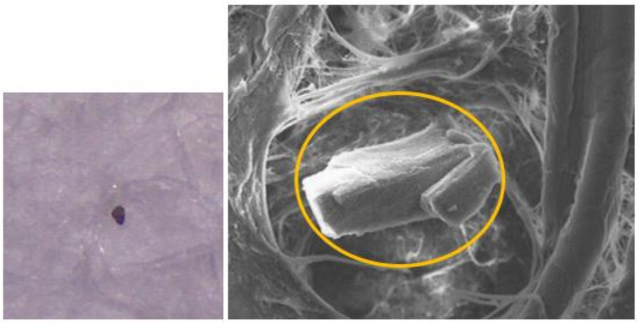

**Figure 8.** Results of Scanning Electron Microscopy (SEM) Analysis of Fragment Shapes in the Intestines of Tiger Shrimp (*P. monodon*)

However, surface patterns can provide clues about the origin of the particles, such as hard plastic fragments or textile fibers.

The porous surface also increases the absorption capacity of contaminants such as heavy metals and toxic compounds [44]. This is reinforced by [45] that these particles are secondary microplastics originating from the fragmentation of macroplastics. SEM images reveal irregular features of microplastics such as cracks, holes, roughness, and split fiber ends, which indicate natural weathering due to exposure to UV, temperature, currents, and waves in the marine environment [46]. In addition, SEM helps explain the formation of secondary microplastics from macroplastic fragments due to photo or thermal degradation. This process alters the properties of polymers, accelerates fragmentation, and increases the amount of microplastics in the water. SEM is also an important tool for assessing the origin and environmental history of these particles [47].

## Conclusion

Based on the research conducted, it can be concluded that the average number of microplastics in the intestines of male tiger shrimp (*P. monodon*) is 16.10 ± 3.75 particles/individual, and in females 18.40 ± 6.60 particles/individual. The dominant microplastics are fragments, blue in color, and 10–50 µm in size in both sexes. Chemically, the microplastics identified are nylon polymers (PA), and SEM results show that the microplastics are secondary microplastics.

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