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Characterization of Microplastic Contamination of Whiteleg Shrimp (*Litopenaeus vannamei*) Cultivation in North Lombok, Indonesia

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ABSTRACT

This study investigates microplastic contamination in whiteleg shrimp (*Litopenaeus vannamei*) cultivation systems, focusing on water, feed, and shrimp health. Microplastics, which pose significant threats to aquaculture, are often ingested by shrimp, potentially causing physiological damage and reducing product quality. The research was conducted from June to September 2024 at PT—X in North Lombok Regency. Samples of water, shrimp organs (intestines, stomach, and gills), and feed (pellets and crumbles) were analyzed for microplastic contamination. Results revealed a high presence of microplastic fragments in both shrimp and feed, with a significant reduction in microplastic particles after water filtration treatment. Specifically, the water reservoir contained 71 microplastic particles before treatment, with fragments being the most prevalent, and decreased to 8 particles post-treatment. The pelleted feed showed 102 microplastic particles, with fragments comprising 90 of them. Similarly, crumble feed contained 49 microplastic particles, predominantly fragments. The findings emphasize the significant role of microplastic pollution from the surrounding environment and the feed production process in shrimp farming. This study provides essential insights into the sources and impact of microplastics on shrimp health and the quality of aquaculture products, advocating for improved management practices and environmental awareness to mitigate contamination risks.

INTRODUCTION

Microplastics have emerged as a significant global environmental issue in recent decades, with this pollutant becoming widespread in aquatic environments, including fisheries ecosystems (Sumsanto *et al*., 2024). Microplastics are defined as plastic particles measuring less than 5 mm that originate from the degradation of large plastics or certain commercial products such as cosmetics and textiles (Lusher *et al*., 2017). Research has shown that microplastics have the potential to have serious impacts on marine life, especially when they accumulate in the body tissues of animals that accidentally ingest them. Microplastics are of great concern in aquaculture because they can affect the quality and health of farmed species (Fred-Ahmadu *et al.*, 2024; Putrajab *et al*., 2024; Saomadia *et al*., 2024).

Whiteleg shrimp (*Litopenaeus vannamei*) is one of the leading fishery commodities that has high economic value, both in local and international markets. Whiteleg shrimp cultivation has developed rapidly due to its quick growth rate and adaptability to varied cultivation environments. However, the presence of microplastics in aquaculture ecosystems can cause various problems, not only in environmental aspects but also in terms of shrimp health and the quality of the products produced. Several studies show that microplastics found in shrimp farming systems can cause physiological disorders in shrimp, such as digestive tract irritation and reduced ability to absorb nutrients (Sahu *et al*., 2024).

Apart from its direct impact on shrimp, microplastics also function as vectors for other pollutants, such as heavy metals, organic pollutants, and dangerous chemicals (Browne, 2013). Microplastics, when ingested, can transport these pollutants into the shrimp's body, leading to the bioaccumulation of hazardous substances that can subsequently reach final consumers via the food chain. This raises concerns about the health of farmed animals and the health of humans who consume contaminated shrimp products (Wu *et al*., 2023).

Several studies have shown that microplastics in shrimp farming feed and water can come from various sources, such as industrial waste and consumer plastic products, as well as the degradation of plastics used in the cultivation process (Sazlı *et al*., 2023). The shrimp can accidentally ingest these particles when they enter the tank water and feeding system. In addition, microplastics originating from the surrounding environment can accumulate in cultivation systems through rainwater runoff, surface washing, or uncontrolled waste disposal (Muhib & Rahman, 2023).

Microplastics in shrimp farming systems not only have an impact on shrimp health but also reduce the quality of cultivated products. Shrimp contaminated with microplastics often experience slower growth and are more susceptible to disease. In addition, the accumulation of plastic particles in shrimp body tissues can disrupt the organoleptic quality of shrimp, including texture and taste (Rochman *et al*., 2013). This has the potential to reduce the commercial value of shrimp, especially in a market that places significant importance on the quality of fishery products.

Research related to microplastic contamination in shrimp cultivation is still developing. Salahuddin *et al*. (2023) have made several efforts to reduce exposure to microplastics in cultivation environments, including by improving the quality of water filtration systems and reducing the use of plastic materials in cultivation areas. However, despite these efforts, major challenges remain in controlling sources of microplastics originating from the external environment, especially from industrial and domestic waste flowing into aquaculture waters (Thompson *et al*., 2009).

In addition, it is important to understand how microplastics affect aquaculture ecosystem dynamics and interactions between aquaculture species and their surrounding environment. Further study of the mechanisms of microplastic bioaccumulation and their impact on animal and human health is a priority in current aquaculture research. Therefore, this research aims to identify the types of microplastics contaminated in the shrimp cultivation system and analyze their impact on shrimp health and the quality of the cultured products (Alberghini *et al*., 2023).

We hope that this research, using comprehensive testing methods, can significantly contribute to efforts to control microplastic contamination in the aquaculture industry. Furthermore, the findings of this study can serve as the foundation for developing better policies for managing the cultivation environment, as well as increasing awareness among fisheries industry players about the importance of maintaining environmental quality so that cultivation results remain optimal and safe for consumers (Ashrafy *et al*., 2023).

METHODS

From June to September 2024, PT—X, located in North Lombok Regency, conducted this research in the whiteleg shrimp cultivation pond. This study aims to characterize microplastic contamination in various components of whiteleg shrimp cultivation, including water, feed, and shrimp bodies, and analyze its impact on shrimp health. Sampling was carried out using purposive sampling, namely a deliberate sampling technique based on certain criteria that are relevant to the research objectives. This study involved taking samples from reservoir water before and after filtration treatment, as well as broodstock, juvenile, and pellet and crumble feed used in cultivation. Water samples were taken from reservoirs using a filtration technique with a 5 µm filter to filter microplastics from the water. We carried out this microplastic sampling technique in water at three reservoir points, using a repetition method to ensure valid sample representation. We filtered each water sample and used a stereoscope at the Fish Health Laboratory, Department of Fisheries and Marine Sciences, Faculty of Agriculture, University of Mataram to identify the microplastics remaining in the filter. Identification of microplastics in water includes the shape and number of particles found. We then quantitatively analyzed this data and compared it between water reservoirs before and after treatment.

For shrimp organ samples, collection was carried out from three main organ parts that have the potential to be contaminated with microplastics, namely the intestines, stomach, and gills. We collect these organs from broodstock and juveniles from ponds. We carefully carried out the sampling technique to ensure there was no external contamination. We process and analyze each taken organ, using a stereomicroscope. We dried the feed samples, which included pellets and crumbles, and then separated them according to the type of microplastics they contained. The feed used in the pond is also checked to determine the potential for microplastic contamination from the feed production process. We classified microplastic fragments found in feed samples based on their type (film, fiber, fragment, and pellet). We carried out the technique of separating microplastics from feed by stirring the feed sample with a saturated salt solution to separate the microplastic particles, which we then filtered and analyzed in the Fish Health Laboratory.

Research parameters include the type of microplastic (film, fiber, fragment, and pellet), shape, and number of microplastic particles. Scientific literature establishes standards for classifying the types of microplastics, grouping them based on their physical shape and color. We conducted descriptive, qualitative, and quantitative data analysis. Quantitative data includes the number and percentage of microplastics found in each component (water, shrimp, feed), while qualitative study focuses on describing the shape and color of microplastics and their potential impact on shrimp health. We then analyzed the results obtained from identifying microplastics in shrimp, water, and feed to see differences in the number and types of microplastics before and after filtration treatment in the water tank.

RESULTS

Microplastic Contamination in Shrimp

In the broodstock white leg shrimp, analysis of microplastic contamination showed the presence of 15 microplastic particles with a predominance of fragment types, namely 14 particles and one film-type particle. No fiber or pellet-type microplastics were found in this sample. These findings highlight that fragments are the form of microplastic that most easily accumulates in shrimp bodies, indicating that the cultivation environment or water sources used have high levels of plastic fragment pollution. Recent research shows fragments often result from the degradation of larger plastic products such as bottles, plastic bags, or cultivation tools made from plastic.

Research on microplastic contamination in juvenile shrimp showed that 21 microplastic particles were identified in the samples. Of this amount, the most dominant type of microplastic was fragments, with 14 particles. Six particles were found in pellets, while only one was found in fiber. The absence of film on juvenile shrimp shows the specific nature of microplastic contamination in this early development stage of white shrimp. The types of microplastics found can provide important information regarding the sources and mechanisms of pollution in cultivation systems.

Microplastic Contamination in Tanks

The total number of microplastics identified in the reservoir before treatment reached 71 particles. Fragments dominated with 38 particles, while 22 film-type microplastics were detected, and pellets reached 11 particles. No fiber particles were found in this reservoir water sample. This microplastic composition indicates significant exposure to plastic contamination in the cultivation environment. The predominant fragments may come from more significant plastic degradation. At the same time, the films and pellets indicate the presence of other sources of contamination, such as industrial waste or the use of plastic equipment around the reservoir.

After applying the treatment, the number of microplastics detected in the reservoir water decreased significantly, from 71 particles to only eight particles. This drastic reduction shows that the treatment method effectively reduces microplastic contamination in the reservoir system. Fragment-type microplastics continued to dominate, with six particles detected, while film type decreased to only two particles. No fiber or pellet-type microplastics were found after treatment. This reduction is important, considering the adverse effects of microplastics on the health of farmed organisms such as shrimp.

Microplastic Contamination in Feed

Recent research revealed that in samples of pelleted feed used in shrimp cultivation, 102 microplastic particles were found. Of this amount, fragment-type microplastics dominate with 90 particles, while the other 12 particles are pellet-type microplastics. The dominance of fragments in pelleted feed is an important finding, considering that microplastic fragments originate from more significant plastic degradation and are widely distributed in the aquatic environment. Lusher *et al*. (2017) stated that microplastic fragments are often found in farmed animal feed, which can potentially enter the aquatic food chain.

Research on microplastic contamination in crumbling feed in shrimp cultivation revealed 49 microplastic particles. Of this number, fragment-type microplastics dominated with 34 particles, while pellet-type microplastics were found with 15 particles. No film and fiber-type microplastics were found in crumble feed samples. These findings reflect a similar pattern to the results found for pelleted feed but with a different composition regarding types and amounts of microplastics. Lusher *et al*. (2017) noted that the type of microplastics in feed can vary depending on the source and production method, which impacts the type and concentration of microplastics detected.

DISCUSSION

Microplastic Contamination in Shrimp

Microplastic contamination in aquatic ecosystems has become a serious concern in the aquaculture industry, especially for white-leg shrimp, one of the leading commodities in aquaculture. Recent research shows that microplastics, especially fragments, have been detected in broodstock and juvenile bodies. This shows that the food chain in the cultivation system has been contaminated with microplastics, which most likely come from the surrounding environment, including the water and feed used. The primary source of microplastics comes from degraded plastic materials, either through natural processes or human activities, such as using plastic equipment in cultivation operations.

Microplastic contamination in shrimp is not only caused by contaminated water but also comes from contaminated feed. Several studies have shown that feed pellets given to shrimp often contain microplastics due to contamination during production or packaging. The shrimp then consumes these pellets containing plastic particles, and the microplastics accumulate in their digestive tract. In the long term, this can affect the overall health of the shrimp, including growth, reproduction, and the quality of the shrimp as a consumer product. The study by *Gola et al*., (2021) also showed that microplastics ingested by aquatic organisms can damage internal organ tissue, negatively impacting physiological function.

Microplastic fragments dominate the particles found in parent and juvenile white shrimp bodies. These fragments are usually tiny and come from various plastic products used around water, such as plastic bags, bottles, and cultivation tools made of plastic. Under the sun's influence of ultraviolet (UV) rays, the plastic undergoes a photodegradation process, breaking down into small particles known as microplastics. This process exacerbates environmental problems because these tiny particles are more difficult to remove from aquatic systems and can be easily consumed by aquatic organisms, including shrimp.

The entry of microplastics into the bodies of shrimp through the food chain significantly impacts the health and sustainability of the shrimp farming industry. Microplastics accumulating in shrimp's body can cause oxidative stress, cell damage, and disturbances in the digestive and reproductive systems. Additionally, microplastics often act as vectors for harmful chemicals, such as persistent organic pollutants (POPs) and heavy metals, which can exacerbate toxicity effects on shrimp. In this context, paying attention to environmental management and control of microplastic sources at cultivation sites is important.

The water used in shrimp cultivation is also an important factor in the spread of microplastics. Several studies show that water from public waters or the sea contaminated with microplastics is at high risk of adding microplastic exposure to the cultivation system. Therefore, more effective filtration and water treatment systems must be implemented to reduce microplastic contamination in the early stages of production. Advanced filtration technologies, such as nano membrane filtration or biological filtration systems, can help reduce the amount of microplastics entering reservoir water or culture ponds.

Microplastic contamination in shrimp cultivation also impacts food safety for consumers. White shrimp contaminated with microplastics can pose a risk to the health of humans who consume them, considering that microplastics can also be a vector for dangerous chemicals. Research by Barboza & Gimenez (2015) shows that microplastics in fishery products can cause hormonal disorders, digestive problems, and other toxic effects in humans. Therefore, stricter steps are needed to manage this risk, including more intensive testing of the quality of shrimp products before they are sold on the market.

Effectiveness of Treatment in Reducing Microplastics in Tandon

The research showed that the treatment applied to the reservoir water reduced the microplastics from 71 particles to 8 particles, indicating the method's effectiveness in reducing microplastic contamination. Salahuddin *et al*. (2023) noted that filtration and water treatment techniques can significantly reduce the amount of microplastics in aquaculture systems, indicating that the treatments applied in this study may involve filtration methods or microplastic separation processes.

Predominance of Microplastic Fragments After Treatment Although the total amount of microplastics significantly reduced, microplastic fragments still dominated after treatment, with 6 of the eight particles detected being fragments. Muhib & Rahman (2023) showed that microplastic fragments are often challenging to remove due to their small size and distribution. Although treatment methods effectively reduce the overall amount of microplastics, controlling tiny microplastics remains a significant challenge.

Treatment Methods Used Various treatment methods have been applied to reduce microplastics in aquaculture systems, including mechanical filtration, coagulation-flocculation processes, and the use of adsorbent media. Albazoni *et al*. (2024) reported that filtration with petite pore sizes can effectively remove microplastics, but smaller fragments often still escape. Therefore, a combination of several treatment methods is often required to treat various sizes of microplastics effectively.

Challenges in Removing Small Microplastics Tiny microplastics, such as remaining fragments, often pass through conventional filtration and treatment systems. Sacco *et al*. (2023) stated that small-sized microplastics are difficult to capture and remove due to their ability to pass through filtration systems with larger pore sizes. This indicates that current treatment technologies may need to be more effective in comprehensively addressing all sizes and microplastics.

The Need for Innovation in Treatment Technology Increasing the effectiveness of microplastic treatment requires innovation in the technology and methods used. *Albazoni et al.* (2024) recommend the development of new technologies, such as filtration systems with nanometer-pore sizes or the use of special adsorbent materials that are more effective in capturing small microplastics. Further research into this technology could provide a more effective solution for microplastic fragments.

Influence on Water Quality and Cultivation Environment The effectiveness of treatment in reducing microplastics also impacts water quality and the aquaculture environment. Khan *et al*. (2023) show that reducing microplastics can improve water quality, supporting the health and growth of aquaculture organisms. However, to maintain sustainability, it is important to continuously monitor and optimize the treatment system to remain effective in the long term.

Microplastic Contamination in Feed

As seen in pellet and crumbling feed samples, microplastic contamination of feed is a significant issue in aquaculture systems. Fred-Ahmadu *et al*. (2024) stated that feed contaminated with microplastics can be the main route for plastic particles to enter the aquaculture food chain. In this study, pellet feed showed the presence of 90 fragment-type microplastic particles and 12 pellet-type particles, while in crumble feed, 34 fragment particles and 15 pellet particles were detected. These findings highlight that feed contains degraded plastic fragments and pellets that may have been contaminated during the production process.

Feed Microplastic contamination in feed can come from various sources, including contaminated feed raw materials or the use of plastic in the feed production process. Tang (2024) explains that microplastics can enter feed through contaminated raw materials or unclean production equipment. Production processes involving the use of plastic can contribute to feed contamination with microplastics, which are then passed on to the farming system.

Microplastics in feed can hurt the quality of cultivation. Rochman *et al*. (2013) reported that microplastics could affect the health and growth of cultured organisms, such as shrimp, through mechanical irritation of the digestive system and the accumulation of harmful chemicals. Microplastic fragments in feed can disrupt the digestive system and reduce nutrient absorption, ultimately affecting shrimp growth and health.

The feed production process, including mixing raw materials and packaging, can also be a source of microplastic contamination. Muhib & Rahman (2023) show that equipment used in feed production can be a source of microplastic contamination if it is not cleaned correctly or uses plastic-based materials. This emphasizes the importance of strict supervision and quality control during the feed production process to reduce the risk of contamination.

More stringent testing and regulations are needed to reduce the risk of microplastic contamination in feed. Rochman *et al*. (2013) recommend routine feed testing for microplastics and implement strict quality standards for raw materials and final products. Stricter regulations in the feed industry could help reduce the possibility of microplastic contamination and ensure better feed quality for aquaculture systems.

Various strategies can be implemented to reduce microplastic contamination in feed, including using plastic-free raw materials and developing cleaner production technologies. Muhib & Rahman (2023) propose the use of alternative materials and improved feed manufacturing systems that can reduce the risk of microplastic contamination. Innovations in feed formulation and production processes will be important to reduce microplastic contamination.

Implications of Microplastic Contamination on Shrimp Health

Microplastic contamination of shrimp, whether through water or feed, has significant health implications. Research shows that ingested microplastics can have various negative impacts on shrimp health. Rochman *et al*. (2013) revealed that microplastics can cause mechanical irritation to the shrimp's digestive tract, affecting the digestive process and nutrient absorption. Microplastic fragments that enter the digestive tract can cause physical damage to the intestinal wall, disrupt the balance of the microbiota, and reduce the efficiency of absorption of important nutrients.

Adverse effects of microplastics on shrimp growth have also been reported. Wu *et al*. (2023) showed that the accumulation of microplastics in the shrimp digestive system can reduce shrimp growth and body weight. Microplastics that interfere with the digestive process decrease conversion efficiency, which can reduce crop yields and affect the quality of the final product from cultivation.

In addition to their direct impact on the digestive system, microplastics can also act as vectors for environmental pollutants such as heavy metals and harmful chemicals. Browne (2013) reported that microplastics can accumulate organic pollutants and heavy metals from the aquatic environment and transfer them into the bodies of organisms that consume them.

These heavy metals and dangerous chemicals can accumulate in the shrimp's body, potentially reducing the quality and safety of aquaculture products.

Microplastic contamination can also affect the health of the shrimp's immune system. Lusher *et al*. (2017) explained that exposure to microplastics can disrupt the function of the shrimp's immune system, increasing susceptibility to infection and disease. Microplastics can affect immune cells' activity and reduce shrimp's ability to fight pathogens, which can affect overall health and farm productivity.

The long-term implications of microplastic contamination for shrimp health must also be considered. Gola *et al*. (2021) showed that the accumulation of microplastics can cause chronic effects such as metabolic disorders and oxidative stress, which can reduce shrimp's longevity and quality of life. This research emphasizes the importance of understanding the long-term impacts of microplastic contamination to plan more effective mitigation strategies. The importance of monitoring and reducing microplastic contamination in aquaculture systems is becoming increasingly apparent. Wu *et al*. (2023) recommend developing better microplastic monitoring and control methods to protect shrimp health and increase aquaculture yields. Implementing effective prevention and control strategies throughout the shrimp farming production chain is very important to reduce the negative impact of microplastics.

Microplastic Control Measures

Based on the results of this research, controlling microplastics in shrimp cultivation is very important to maintaining shrimp health and the quality of cultivated products. Salahuddin *et al*. (2023) underlined that one of the main steps in overcoming microplastic contamination is improving water quality through a more efficient filtration system. An effective filtration system can capture microplastic particles in the water and reduce the number of contaminants entering the cultivation system. Advanced filtration technologies, such as membrane filters and high-pressure systems, can help reduce microplastic contamination in reservoir water and culture ponds.

Additionally, Thompson *et al*. (2009) recommend implementing better microplastic detection technology to monitor contamination in feed. Regular feed testing can ensure that the feed used in cultivation does not contain microplastics. Analytical methods such as digital microscopy and FTIR spectroscopy can accurately identify and quantify microplastics in feed. By ensuring feed is free from microplastics, the risk of shrimp contamination through feed can be minimized.

Implement mitigation strategies to reduce sources of microplastic contamination in the environment around cultivation. Rochman *et al*. (2013) emphasize that effective waste management and monitoring sources of contamination in the aquatic environment are important steps in reducing the amount of microplastics carried into aquaculture systems. Efforts such as improving waste management, reducing the use of single-use plastics, and monitoring coastal areas can help reduce the amount of microplastics entering the farming environment.

Using innovative technology to reduce microplastics is also an important strategy. Sacco *et al*. (2023) show that technologies such as coagulation-flocculation and gravity-based separation can reduce the amount of microplastics in reservoir water. This technology helps to efficiently settle and remove microplastic particles from water, thereby reducing the potential for contamination in shrimp farming systems.

Additionally, Arienzo *et al*. (2021) recommend implementing a continuous monitoring system and training for shrimp farmers to increase awareness about the dangers of microplastics. A monitoring system that includes regular testing and training will help farmers identify and address microplastic problems quickly and effectively. Education about good management practices and prevention techniques can improve farmers' ability to reduce microplastic contamination.

Using environmentally friendly alternative materials in feed production can also strengthen microplastic control. Wu *et al*. (2023) highlighted that using feed ingredients that are not easily degraded into microplastics or can be digested well by shrimp can reduce contamination. Further research into feed formulations that reduce the potential for microplastics will provide a long-term solution to this problem.

Overall, controlling microplastics in white leg shrimp cultivation requires a multi-faceted approach involving improving filtration technology, feed testing, plastic waste management, use of innovative technology, monitoring systems, and application of alternative materials. Implementing these strategies together will help reduce microplastic contamination and improve the quality and sustainability of shrimp farming.

CONCLUSION

This research reveals high levels of microplastic contamination in white leg shrimp cultivation, which is dominated by fragment-type particles. Microplastics are found in broodstock and juvenile bodies, tank water, and feed used in cultivation systems. Microplastic fragments mainly come from the degradation of large plastics such as bottles and plastic cultivation tools, while raw materials and production processes cause feed contamination. This research also shows that treatment of stored water has reduced microplastics significantly, although small fragments remain challenging to remove. These findings highlight the threat to shrimp health and aquaculture product quality due to exposure to microplastics.

To reduce microplastic contamination, an integrated approach is needed that includes advanced filtration technology, regular feed testing, plastic waste management, and innovation in feed formulation. Microplastics not only affect shrimp's health through tissue damage and digestive disorders but can also act as a vector for dangerous chemicals that threaten food safety for consumers. Developing better microplastic detection methods and training for shrimp farmers is important to ensure the sustainability of farming and reduce the risk of contamination in the aquatic food chain.

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