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RESEARCH ARTICLE

Microplastic Contamination of Four Important Commercial Fish in East Coast of North Sumatera Province, Indonesia

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ABSTRACT

This study aims to identify microplastic pollutants of four important commercial fish (*Johnius borneensis*, *J. macropterus*, *Osteomugil engeli*, and *Sardinella fimbriata*) in the east coast of North Sumatra Province, Indonesia. The study was conducted from May to December 2022 in Langkat, Deli Serdang, Serdang Begadai and Batu Bara Regency, Indonesia. Microplastic analysis was conducted at the Biology Laboratory, Faculty of Mathematics and Natural Sciences, Universitas Negeri Medan, Indonesia. The microplastic extraction process was started by inserting the target fish organs into 10% KOH solution (1:10 ratio), then incubated for 12 hours at 60°C. Furthermore, the decomposed fish organs were filtered using Whatman No. 540, assisted by a vacuum machine; then the filter results were incubated at 50°C for 5 hours so that the liquid on the filter paper evaporated. The results of the analysis of microplastics in four fish species showed that the highest prevalence value was in *O. engeli* and *J. borneensis* reaching 98%, followed by *S. fimbriata* 92%, and *J. macropterus* 87%. Based on the total microplastics analyzed by species, *J. borneensis* had the highest value, reaching 513 particles, followed by *S. fimbriata*, 472 particles, *O. engeli*, 433 particles, and *J. macropterus*, 279 particles, where each intensity value reached 5.23, 5.13, 4.42, and 3.21 microplastics/fish. The results of microplastic analysis showed that the most dominant transparent color was found in *O. engeli* and *J. borneensis*, with values reaching 35% and 30%, while in S. fimbriata, black color reached 33%, and in *J. macropterus,* brown color reached 38%. Furthermore, from a total of 1,697 microplastics from 4 fish species, the highest size found was in the size range of 105–500 µm reaching 55% with details of 31% film, 20% fiber, and 4% fragment.

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1. INTRODUCTION

Microplastics are inorganic waste that accumulates in waters measuring < 5 mm to the smallest nanoparticle size and is a very significant threat to global environmental conditions (Avio et al. 2015; Lozoya et al. 2016). The process of microplastic formation is due to fragmentation and degradation of macro-sized plastic waste through impact and water chemical activity (Compa et al. 2018). This microplastic waste has polluted the environment, including marine, freshwater, and estuary ecosystems around the world (Lusher et al. 2017). Digested microplastic waste was recorded in fish, zooplankton, crustaceans, invertebrates, seabirds, turtles, and mammals (Cole et al. 2013; Jabeen et al. 2017; Abbasi et al. 2018). Based on the polymer structure, microplastics are divided into polystyrene, polypropylene, polyethylene, polyethylenterephthalate, styrene-acrylate, alkyd resin, rayon, polyester, nylon, and acrylic (Neves et al. 2015).

Microplastics that enter the aquatic environment in addition to being pollutants, also have a negative impact on aquatic organisms (Lusher et al. 2013; Foley et al. 2018). This is because every year 240 million tons of plastic waste are produced by humans and pollute the oceans (Mathalon and Hill 2014). The negative impact of microplastics on organisms is physiological and behavioral. The physiological effects of microplastics on aquatic organisms include obstruction of the digestive tract, stunted growth, inhibition of hatching eggs, liver toxicity, and reproductive disorders (Jovanović 2017; Menezes et al. 2019). The impact of microplastics on the behavior of aquatic organisms is in the form of changes in innate behavior, eating preferences, and death (Lönnstedt and Eklöv 2016).

Research on microplastics has become a global environmental issue, so several studies have been reported. The studies that have been reported are about the concentration of microplastics in water on Geoje Island, South Korea (Song et al. 2015), North Atlantic Ocean (Lenz et al. 2015), and Coastal Spain (Gago et al. 2015). Furthermore, microplastic studies in sediments have been carried out in the Southern Waters of Portugal (Frias et al. 2016), Nova Scotia, Canada (Mathalon and Hill 2014), Slovenia (Laglbauer et al. 2014), Bizerte, Tunisia (Abidli et al. 2017), Canary Islands, Spain (Herrera et al. 2018) and Lombok, Indonesia (Cordova et al. 2018). Further research on microplastic contamination in fish has also been carried out by Jabeen et al. (2017) in China, Avio et al. (2015) in the Italian Adriatic Ocean, Lusher et al. (2013) in Plymouth UK, Neves et al. (2015) on the coast of Portugal, Foekema et al. (2013) in North Sea, Netherlands, Bellas et al. (2016) in Spanish Mediterranean and Atlantic waters, Rummel et al. (2016) in the Baltic Sea, Nadal et al. (2016) and Alomar et al. (2017) in the Balearic Islands and the Mallorca Palma Islands, Vendel et al. (2017) on the northern coast of Brazil and Murphy et al. (2017) in the Northeast Atlantic, Scotland. Meanwhile, research on microplastic contamination of fish in Indonesia is still very rarely done, even especially *Johnius borneensis*, *J. macropterus*, *Osteomugil engeli*, and *Sardinella fimbriata* in North Sumatra Province, so it is important to study it, considering that Indonesia is one of the 10 largest human populations in the world which has the potential to contribute to plastic waste significantly.

The research on microplastics that has been carried out in Indonesia is the contamination of microplastic particles and fiber in fish in Makassar (Rochman et al. 2015), microplastics in deep-sea sediments in the Southwest of Sumatra (Cordova and Wahyudi 2016), the abundance of microplastic waste in Coastal Cilacap (Syakti et al. 2017), microplastic abundance in sediments in Jakarta Bay (Manalu et al. 2017), microplastic contamination in Bintan waters, Riau Islands (Syakti et al. 2018), microplastic waste from the Pacific to the northern waters Indonesia (Ramos et al. 2018), abundance of microplastics in coral reef sediments in Sekotong, Lombok (Cordova et al. 2018) and distribution of microplastics in water and sediments in the Ciwalengke River, Majalaya (Alam et al. 2019). Thus, it is important to conduct and discuss the study of microplastic contamination in four commercial fish in North Sumatra. This is related to food security and human health (Barboza et al. 2018).

2. MATERIALS AND METHODS

2.1 Time and site

This research was conducted from May to December 2022 at the Biology Laboratory, Faculty of Mathematics and Natural Sciences, Universitas Negeri Medan, Indonesia. Fish samples used for microplastic analysis were collected from fish landing sites from Langkat (4°4'36.584" N, 98°19'1.679" E), Deli Serdang (3°40'47.273" N, 98°54'27.076" E), Serdang Bedagai (3°30'28.580" N, 99°14'14.932" E), and Batu Bara (3°25'40.573" N, 99°19'53.191" E) Regency, North Sumatra Province, Indonesia (Figure 1).

2.2 Research procedure

Determination of fish samples was carried out based on the fish species. A total of 100 samples per fish species were collected (Karami et al. 2018). The collected samples were then put into a styrofoam box and taken to the Biology Laboratory, Faculty of Mathematics and Natural Sciences, Universitas Negeri Medan, Indonesia, for further analysis.

2.3 Microplastic extraction

The fish samples that had been brought to the laboratory were then measured for total length using a digital caliper (error = 0.01 mm) and the weight using a digital scale (error = 0.01 g). The fish is then dissected starting from the anal, pointing vertically 60 degrees to the boundary before the linea lateralis, then dissected horizontally towards the gills of the fish (Batubara 2019). This surgical technique is carried out so that the internal organs of the fish are not damaged and facilitates the process of organ separation. After that, the surgical section of the fish is opened, and then the intestinal organs are separated for the extraction process.

The microplastic extraction process was carried out according to Karami et al. (2017); fish tissue was put into a 10% KOH solution (1:10 ratio) and then incubated for 12 hours at 60°C. Furthermore,

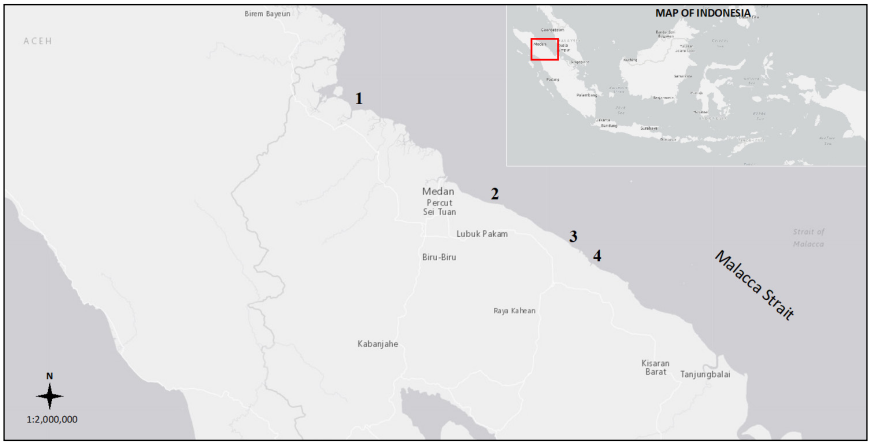

Figure 1. Map of research location, where (1) Langkat (4°4'36.584" N, 98°19'1.679" E), (2) Deli Serdang (3°40'47.273" N, 98°54'27.076" E), (3) Serdang Bedagai (3°30'28.580" N, 99°14'14.932" E), and (4) Batu Bara (3°25'40.573" N, 99°19'53.191" E) Regency, North Sumatra Province, Indonesia are located.

the fish tissue that has been decomposed is filtered using Whatman paper (no. 540) assisted by a vacuum machine; then, the filter results were incubated at 50°C for 5 hours so that the liquid on the filter paper evaporated. The dried filter paper was then stored in a petri dish for the identification and calculation of microplastics through a microscope.

2.4 Observation parameter

Identification and counting of microplastic particles were carried out optically using a binocular (Olympus CX21) and stereo (Zeiss Stemi 2000-C) microscope. The calculation of microplastic particles was carried out based on the type (fraction, fiber, sheet, and expanded polystyrene (EPS)) referring to Song et al. (2015). The prevalence, intensity, and frequency of microplastic particles based on type, size, and color were analyzed using the formula of Karami et al. (2018) and Roch et al. (2019): Prevalence = Total fish contaminated with microplastics / Total fish samples × 100; Intensity = Total microplastics / Total fish contaminated with microplastics.

2.5 Data analysis

The data on the prevalence, intensity, and frequency of microplastics obtained are presented in tables or figures and then analyzed descriptively based on fish species, color, and size of microplastic.

3. RESULTS

The results of the analysis of microplastics in four fish species showed that the highest prevalence value was in *Osteomugil engeli* and *Johnius borneensis*, reaching 98%, followed by *Sardinella fimbriata* at 92%, and *Johnius macropterus* at 87%. Based on the total microplastics analyzed by species, *J. borneensis* had the highest value, reaching 513 particles, followed by S. fimbriata, 472 particles, O. engeli, 433 particles, and *J. macropterus*, 279 particles, where each intensity value reached 5.23, 5.13, 4.42, and 3.21 microplastics/fish (Table 1).

The types of microplastics identified during the research were fibers, films, and fragments (Figure 2). Based on the type of microplastic and fish species, *O. engeli* accumulated microplastics with details of 371 fibers, 37 fragments, and 25 films; *S. fimbriata* reached 283 fibers, 153 films, and 36 fragments; *J. borneensis* reached 230 films, 227 fibers, and 56 fragments; *J. macropterus* reached 168 fibers, 81 films, and 29 fragments (Table 2). Based on the prevalence value, it showed type of microplastics that fiber reached 98%, fragment 22%, and film 26% in *O. engeli*; fiber up to 82%, fragment 62%, and film 22% in *S. fimbriata*; fiber

Table 1. Data on prevalence and intensity of microplastics based on fish species in the intestinal organs.

Species	∑ Sample	∑ Microplastics	Intensity (microplastics/fish)	Prevalence (%)
Osteomugil engeli	100	433	4.42	98
Sardinella fimbriata	100	472	5.13	92
Johnius borneensis	100	513	5.23	98
Johnius macropterus	100	279	3.21	87

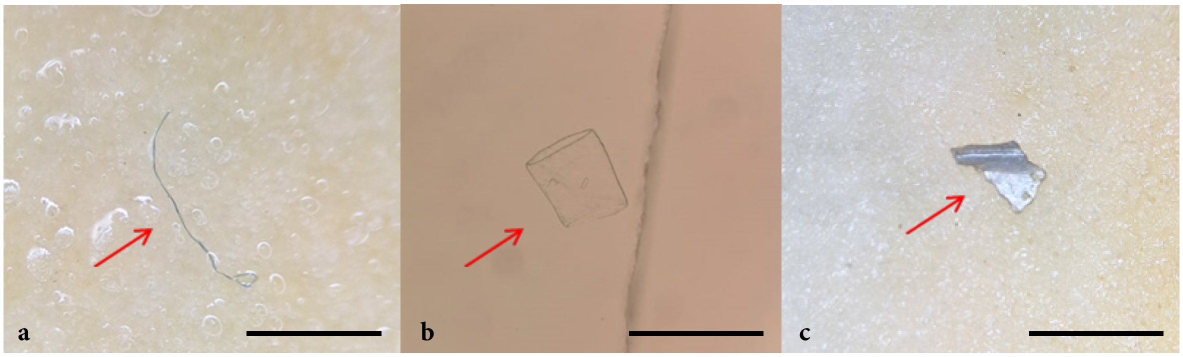

Figure 2. Types of microplastics found in the intestinal organ of fish: (a) fragment, (b) film, and (c) fiber. Scale bar = 1 mm.

Table 2. Data of microplastics type based on fish species in the intestinal organs.

Species	Microplastic Type	∑ Sample	∑ Microplastics
Osteomugil engeli	Fiber	100	371
	Film	100	25
	Fragment	100	37
Sardinella fimbriata	Fiber	100	283
	Film	100	153
	Fragment	100	36
Johnius borneensis	Fiber	100	227
	Film	100	230
	Fragment	100	56
Johnius macropterus	Fiber	100	169
	Film	100	81
	Fragment	100	29

up to 85%, fragment 82%, and film 36% in *J. borneensis*; fiber reached 68%, fragment 33%, and film 24% in *J. macropterus* (Figure 3a). Based on the intensity value, it showed that microplastic fiber type reached 3.86, fragment 1.14, and film 1.42 microplastics/fish in *O. engeli*; fiber reached 3.45, fragment 2.47, and film 1.64 microplastics/fish in *S. fimbriata*; fiber reached 1.86, fragment 2.80, and film 1.56 microplastics/fish in *J. borneensis*; fiber reached 2.49, fragment 2.45, and film 1.21 microplastic/fish on *J. macropterus* (Figure 3b).

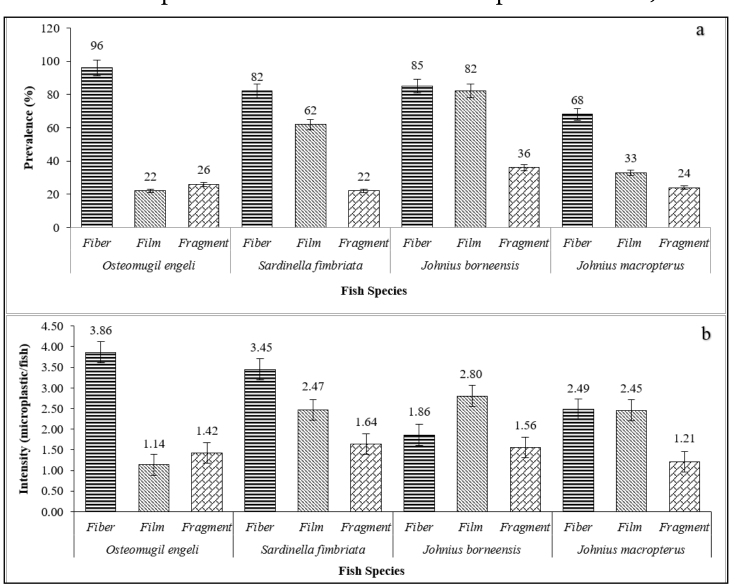

Figure 3. Microplastic prevalence (a) and intensity (b) values based on fish species and microplastic type in the intestinal organs.

The results of microplastic analysis showed that the most dominant transparent color was found in *O. engeli* and *J. borneensis* with values reaching 35% and 30%, while in *S. fimbriata*, black reached 33%, and in *J. macropterus,* brown reached 38% (Figure 4). Furthermore, from a total of 1,697 microplastics from 4 fish species, the highest size found was in the size range of 105–500 µm, reaching 55% with details of 31% film, 20% fiber, and 4% fragment (Figure 5).

4. DISCUSSION

Microplastics enter the fish body through the mouth and gills and then are distributed to the intestinal organs (Jabeen et al. 2017). Microplastics that are in the sediment and water column enter the body of biota due to a misconception that microplastics are food (Abbasi et al. 2018). Furthermore, according to Cardozo et al. (2018), the bioaccumulation of microplastics in biota is closely related to prey organisms associated with microplastics in the bottom or water column.

Water columns that are mixed with pollutants, monomers, and plastics are addictive and have a direct or indirect impact on the health of aquatic biota. The factors that cause the entry of microplastic pollutants into water bodies are garment industry waste (Browne et al. 2011), increased tourist activity on the beach (Laglbauer et al. 2014), increased consumer use of plastic, and poor management of plastic waste

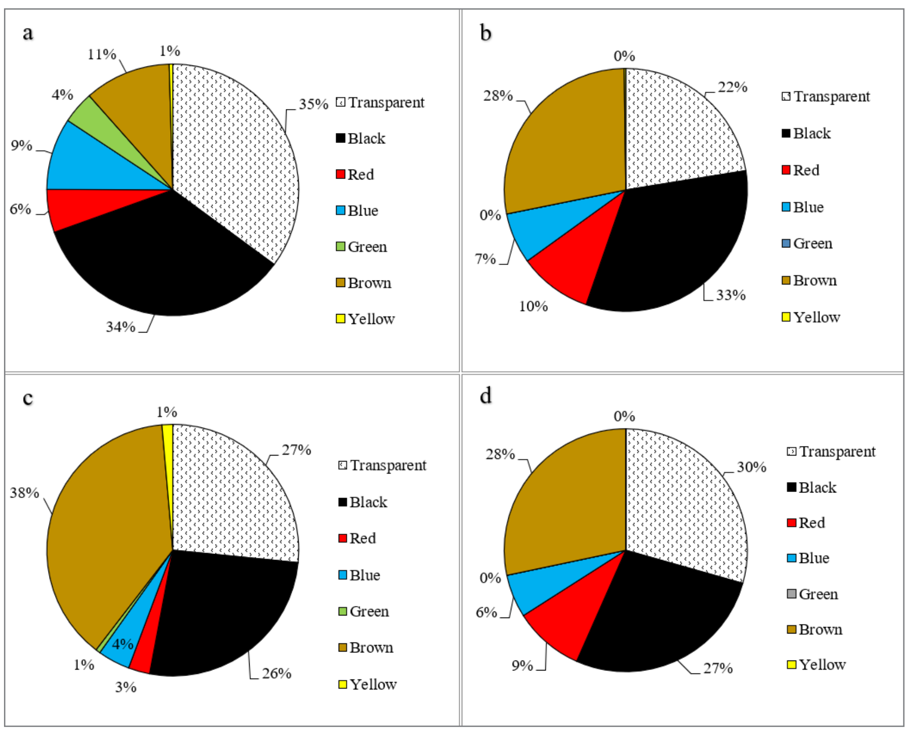

Figure 4. Microplastic color frequency based on fish species, where (a) *Osteomugil engeli*, (b) *Sardinella fimbriata*, (c) *Johnius borneensis*, and (d) *Johnius macropterus*.

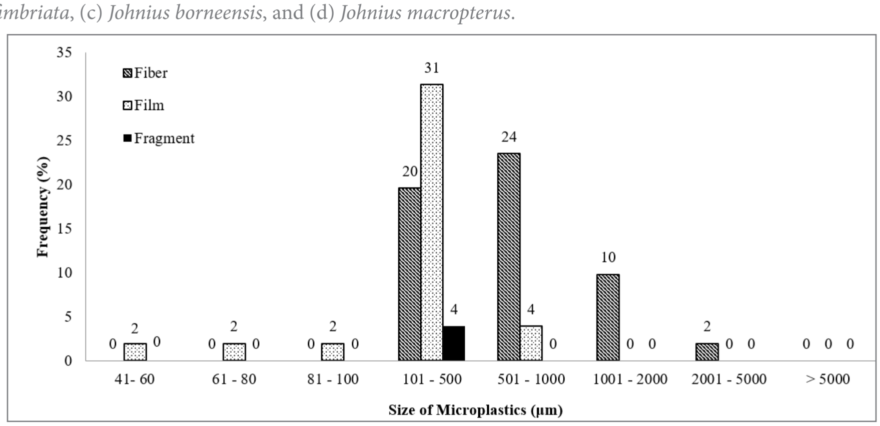

Figure 5. Microplastic frequency based on size and type of microplastics on four fish species.

treatment (Santana et al. 2016). In addition, the buoyancy and persistence give the potential for microplastics to be widely distributed throughout the world through hydrodynamic processes and ocean currents (De-Carvalho and Neto 2016).

Sources of microplastic pollutants at the four research locations are related to several operating industries, poor waste management, minimal waste handling infrastructure, low public awareness, and shipping activities in the Malacca Strait (Syafrudin et al. 2023). Based on the research results of Khair et al. (2019), household activities contribute > 30% of waste in Medan, North Sumatra, with details of 61.35% organic waste, 17.55% plastic waste (bottles, plastic bags, and toys), 8.2% paper waste, and 12.90% other waste (cloth, glass, leather, rubber, and wood). Sources of microplastic pollutants of fibers, films, and fragments are inorganic waste in the form of bottles, cloth, food packaging, fishing nets, plastic bags, ship rope, rubber, toys, and wrappers (Hasibuan et al. 2023; Liotta et al. 2024).

According to Fatema et al. (2013) and Hatia et al. (2021), the Mugilidae group (*O. engeli*) and *S. fimbriata* consume foods from the plankton group. Previous research revealed that the volume of microplastic waste digested by zooplankton reached 1.7–30.6 m of the polystyrene type (Cole et al. 2013). This may be one of the causes of microplastic contamination in *O. engeli* and *S. fimbriata*. Furthermore, the thing that causes the entry of microplastics in the digestion of zooplankton is the high abundance of microplastics (the ratio of microplastics and zooplankton reaches 0.5:1) in the waters so that it confuses zooplankton in selecting food (Collignon et al. 2012). The phenomenon of microplastic ingestion by zooplankton suggests that species at lower trophic levels in marine food webs mistake plastic for food, which raises fundamental questions about the potential risk to species at higher trophic levels (Desforges et al. 2015). Rummel et al. (2016) revealed filter feeder (plankton feeder) fish are more prone to microplastic accumulation, because microplastics that are also filtered can enter the digestive tract.

J. borneensis and *J. macropterus* are carnivorous fish, when they were juvenile, they used to eat shrimp, and when they got bigger, they started eating crabs and benthopelagic fish (Simanjuntak et al. 2022). So, it is estimated that the microplastics that enter their bodies are accumulations of microplastics that are ingested by their prey (Mizraji et al. 2017). In addition, the error in detecting food (biomagnification) is also the cause of microplastic accumulation in this group of fish (Ismail et al. 2019). Therefore, microplastics will accumulate in the digestion of fish which can trigger oxidative stress and inflammation (Jabeen et al. 2017).

In addition to fish, commercial shellfish *Perna perna* on the coast of São Paulo City, Brazil, have been shown to contain microplastic debris. This is a growing problem for both humans and the environment as a result of rising consumption and cultivation (Santana et al. 2016). Furthermore, research conducted by Mathalon and Hill (2014) showed that the shellfish *Mytilus edulis* had been contaminated with microplastics in Nova Scotia, Canada. There were also reports of more microplastic contamination in the crab *Carcinus maenas* and shellfish *Mytilus edulis* (Farrell and Nelson 2013).

5. CONCLUSION

Four economically important fish species have been identified contaminated by microplastic in the intestinal organs, with a prevalence value of 98% for *O. Angeli* and *J. borneensis*, followed by *S. fimbriata* at 92% and *J. macropterous* at 87%. This data indicates a concerning abundance of microplastics being released into the water, necessitating urgent collective action to reduce plastic waste and raise environmental awareness.

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AUTHOR CONTRIBUTIONS

Rahmatsyah R: Conceptualization, Formal analysis, Investigation, Writing – original draft. **Syarifuddin S:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Resources, Project administration, Writing – review & editing. **Juliani R:** Conceptualization, Investigation, Methodology, Writing – review & editing. **Azzahra AF:** Data curation, Formal analysis, Writing–review & editing. **Rahmeida S:** Data curation, Formal analysis, Writing–review & editing. **Batubara AS:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Resources, Writing – review & editing.

CONFLICTS OF INTEREST

All authors declare no conflict of interest.

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