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THE EFFECTS OF FERMENTED BANANA STEM (*Musa paradisiaca*) IN REDUCING ECTOPARASITE INFESTATION IN FARMED RED TILAPIA (*Oreochromis niloticus*)

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ABSTRACT

Tilapia is a widely farmed freshwater fish due to its fast growth and disease resistance. However, ectoparasite infestations hinder its health and growth. Antibiotics are commonly used to treat these parasites, but their negative effects have led to the search for alternatives, such as banana (*Musa paradisiaca*) stem. This study evaluated the effects of different doses of fermented banana stem on ectoparasite mortality in red tilapia (*Oreochromis niloticus*). The experiment included treatments with fermented banana stem at concentrations of 5 $g.L^{-1}$, 10 $g.L^{-1}$, and 15 $g.L^{-1}$, along with a control group. The fish samples were obtained from a goverment owned farming pond facility and a fish market with the average sizes of 10.2 ± 3.8 cm and 7.5 ± 1.3 cm, respectively. Farmed tilapia from the market pond had more ectoparasites compared to the fish collected from the government farming facility. The identified parasites were: *Trichodina* sp., *Dactylogyrus* sp., *Gyrodactylus* sp., *Ichtyophtirius multifilis*, and *Oodinium* sp. The result showed that the fermented banana stem had different effective time in eradicating different ectoparasites ranged from 480-840 s for *Trichodina* sp., followed by 1380-1920 s for *Dactylogyrus* sp., and 2040-2640 s for *Gyrodactylus* sp. At concentrations of 10–15 $g.L^{-1}$, it significantly accelerated parasite mortality and increased tilapia survival rates by up to 80%. This study concludes that bioactive compounds in fermented banana stem effectively treat ectoparasites disease attacks and improve fish health.

KEYWORDS: banana stem; ectoparasites; survival rate; tannin; tilapia

ABSTRAK: ***Pengaruh Fermentasi Batang Pisang (**Musa paradisiaca**) dalam Mengurangi Infestasi Ektoparasit pada Budidaya Ikan Nila Merah (**Oreochromis niloticus**)***

*Ikan nila merupakan salah satu ikan air tawar yang banyak dibudidayakan karena pertumbuhannya yang cepat dan ketahanannya terhadap penyakit. Namun, infestasi ektoparasit dapat menghambat kesehatan dan pertumbuhannya. Antibiotik umumnya digunakan untuk mengobati jenis parasit ini, tetapi dampak negatifnya mendorong pencarian alternatif, seperti batang pisang (**Musa paradisiaca**). Penelitian ini mengevaluasi pengaruh berbagai dosis fermentasi batang pisang terhadap mortalitas ektoparasit pada nila*

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*merah (**Oreochromis niloticus**). Percobaan melibatkan perlakuan dengan fermentasi batang pisang pada konsentrasi 5 g.L^{-1}, 10 g.L^{-1}, dan 15 g.L^{-1}, serta kelompok kontrol. Sampel ikan diperoleh dari kolam budidaya milik pemerintah dan pasar ikan, dengan ukuran rata-rata masing-masing 10,2 ± 3,8 cm dan 7,5 ± 1,3 cm. Ikan dari pasar memiliki lebih banyak ektoparasit dibandingkan dengan ikan dari fasilitas pemerintah. Parasit yang teridentifikasi meliputi **Trichodina** sp., **Dactylogyrus** sp., **Gyrodactylus** sp., **Ichthyophthirius multifiliis**, dan **Oodinium** sp.. Hasil penelitian menunjukkan bahwa fermentasi batang pisang memiliki efektivitas waktu berbeda dalam membasmi ektoparasit, berkisar antara 480–840 detik untuk Trichodina sp., 1380–1920 detik untuk **Dactylogyrus** sp., dan 2040–2640 detik untuk **Gyrodactylus** sp.. Pada konsentrasi 10–15 g.L^{-1}, fermentasi batang pisang secara signifikan mempercepat kematian parasit dan meningkatkan kelangsungan hidup ikan hingga 80%. Penelitian ini menyimpulkan bahwa senyawa bioaktif dalam batang pisang terfermentasi efektif dalam mengobati serangan penyakit akibat ektoparasit dan meningkatkan kesehatan ikan nila.*

KATA KUNCI: batang pisang; ektoparasit; ikan nila; kelulushidupan; tannin

INTRODUCTION

Tilapia (*Oreochromis niloticus*) is a freshwater fish originated from the East African region. It has been widely farmed in Indonesia because of its well established farming methods and relatively fast harvest time. Tilapia production has increased annually around 9.2% from 1.084.281 tons in 2015 to 11.474.742 tons in 2019 (Kementerian Kelautan dan Perikanan, 2020). Tilapia is widely cultivated in various regions of Indonesia because it has high economic demands. Red tilapia is one of the most sought after tillapia strains due to its superiorty in terms of responsiveness to feed, faster growth rate, high survival rate, resistancy to disease attacks, high tolerance to environmental conditions, and easy to breed. The strain is well documented for its nutritional benefits, including high levels of omega-3 fats and vitamins B and D. Red tilapia is known for its fast growth rate, which allows for multiple farming cycles per year and makes it an ideal candidate for small-scale aquaculture operations (Ekasari *et al*., 2023; Mohammadiazarm *et al*., 2023; Sallam *et al*., 2024).

However, the rapid development of tilapia aquaculture cannot be separated from the challenges that the farmers face, including ectoparasite infestations. This ectoparasite lives and develops on the surface of the fish's body. The presence of ectoparasites in tilapia negatively affects their condition and overall health. The ectoparasitic burden is also associated with increased production of gill mucus, which increase energy expenditure in the fish, further exacerbating the adverse effects (Kolia *et al*., 2021; Paredes-Trujillo *et al*., 2021). Firdausi *et al*. (2020) argue that ectoparasite infestation can cause financial losses to fish farmers due to reduced fish productivity and quality susequently leading to reduced fish selling prices. Consuming fish infected with parasites could potentially cause human health problems if not processed properly (Maulana *et al.*, 2017; Shamsi *et al.*, 2019).

The most common treatment for ectoparasites is by administering antibiotics. Continuous administration of antibiotics in fish treatment can cause negative impacts, such as increasing pathogen resistance and leaving antibiotic residues in the water (Azhar *et al*., 2020; Yang *et al*., 2020). Therefore, it is necessary to carry out alternative treatments for ectoparasites in fish, such as natural ingredients. Banana (*Musa paradisiaca*) stems contain tannins, flavonoids, terpenoids, alkaloids, glycosides, and phlobatnin.

The tannin compound is an antimicrobial, antiparasitic, antiviral, antioxidant, and anti-inflammatory (Ighodaro, 2012; Rochana *et al.*, 2017).

Natural ingredients can produce healing substances through fermentation, and banana stems can be used to treat fish. Fermentation converts organic materials into simpler substances through biochemical processes assisted by microorganisms. This process is well-known and used in the food sector. In medicine, especially animal medicine, fermentation is rarely used, but in several cases, fermentation is used to minimize the negative impact of chemical drugs. Fermentation can help release the nutrients found in banana stems. Banana stems contain suitable substances useful in the healing and treatment process. The antibiotic in banana stems can provide an antioxidant effect, speeding up wound healing (Ananta, 2020; Labatar, 2018). Miranti and Abdul (2018) stated that the fermentation of betel and surian leaves could produce substances that effectively treat wounds caused by parasites and improve the healing process of betta fish. Amalia *et al*. (2023) stated that fermented banana stem is a source of probiotics and helps the growth and survival of *Cyprinus carpio.*

Research on using banana stem fermentation against ectoparasites in red tilapia is rarely conducted in controlled and uncontrolled locations. This research aimed to determine the effect of banana stem fermentation dose on the mortality of ectoparasite in red tilapia. It is hoped that with this research, fermented banana stems can be used as an alternative treatment for parasites in fish to reduce the use of chemicals that tend to be more dangerous and not environmentally friendly.

MATERIALS AND METHODS

Sampling

The ectoparasite identification process began with the fish sampling stage. The method used in sampling was purposive sampling as described in Suharsimi (2006) by considering the following criterion. The farmed live fish samples selected to be used in observing ectoparasites infestation were sick fish showing visual clinical signs of parasitic infestation. Based on this criterio, there were 30 fish samples collected from the pond of the Aquaculture Technology Development Center (BPTPB) Argomulyo, Cangkringan with an average size of 10.2 ± 3.8 cm and five fish samples from the Cangkringan Market sized of 7.5 ± 1.3 cm. The use of the test fish in this experiment refers to national standards followed the standard of animal use in research issued by the Badan Standarisasi Nasional (2009) SNI: 7306:2009.

Clinical Symptoms

The clinical symptoms observed in the study consisted of morphological and behavioral symptoms, which are the initial stages for detecting ectoparasite presence. The observation of clinical symptoms of fish attacked by ectoparasites was carried out by external observation or observed signs on the outside of the fish's body, such as skin, gills, and fins. Fish attacked by ectoparasites will show morphological symptoms such as thin fins, ulcers, and excess mucus production. Meanwhile, symptoms of abnormal behavior include swimming on the surface, decreased appetite, and rubbing his body against the wall of the pond.

Parasite Identification

The observation of ectoparasites began by preparing the samples using a native method by scraping the skin and gills (right and left). Sample preparation was carried out while the fish were still alive. Sample scraping was carried out using a scalpel. The scrapped samples were placed on a glass object and observed using a microscope with 4x magnification followed by 10x magnification. Morphological observations were carried out to identify the type of ectoparasite found. Additional calculations were carried out on ectoparasites found to determine their intensity and prevalence values.

The intensity of ectoparasite was calculated before the treatment using the equation (1) suggested by Cameron (2002):

$$Intensity = \frac{Total\ Parasite\ found\ in\ fish}{Total\ infected\ fish} \quad ....(1)$$

The ectoparasite prevalence value was determined using the equation (2) suggested by Cameron (2002):

$$Prevalence\ (\%) = \frac{Total\ of\ infected\ fish}{Total\ Fish} \times 100 \quad ....(2)$$

Fermentation of Banana Stem

Fermented banana stem was made by chopping one banana stem into small pieces. The treatment A, B and C consisted of 5 g, 10 g, and 15 g of chopped banana stem. Each weighed banana stem was placed into a plastic/glass bottle and then, added with 1 L of water and closed tightly. The soaking was done for approximately 2-3 weeks until the banana stems formed fibres. Afterward, the solution was mixed homegenously with 1.5 g of shrimp paste, which had previously been dissolved in water. The mixture was left to be fermented until it changed color to golden yellow and had no strong odor.

Treatment of Ectoparasites with Banana Stem Fermentation Solution

The collected ectoparasites were then treated with the banana stem fermentation and observed to determine the level of effectiveness of banana stem fermentation (the length of time the ectoparasites died). The ectoparasites were dripped with two drops of fermented banana stems and then observed under a microscope until the ectoparasites died and recorded the time (s). To determine whether the ectoparasites have died under a microscope, the study relied on any of the following visual signs or ectoparatise characteristics: (1) Dead ectoparasites showed signs of disintegration, such as fragmentation or dissolution of their bodies; (2) Live ectoparasites exhibited movement when observed under a microscope. If the parasites no longer moving, it indicated that they have died; and (3) Dead parasites may change color or become more transparent (Kismiyati *et al.*, 2024; Mathison & Pritt, 2014; Wells *et al.*, 2012).

Survival Rate

Ectoparasite-infected fish from the BPTPB Cangkringan pond were placed in separate buckets and treated using the treatment solutions for 7 days to determine the impact of treatment on the fish survival rate. The treatments were carried out using immersion with 10 $mL.m^{-3}$ with slight modifications (Pricilia *et al*., 2017). The survival rate of sampled tilapia was calculated using the formula (3) according to Jaya *et al.* (2013):

$$SR = \frac{Nt}{N0} \times 100 \quad ....(3)$$

SR: Degree of survival (%); Nt: Number of survival fish at the end of rearing (ind); N_0: Number of fish at the initial of rearing (ind).

Water Quality

Water quality observations were carried out every day (morning and evening) at each location, and they included pH using a pH meter and dissolved oxygen (DO) by using a DO meter.

Data Analysis

The collected data were analyzed using a descriptive–comparative method with a qualitative approach.

RESULTS AND DISCUSSION

Clinical Symptoms

The sample used in the observations was sick red tilapia. Infected fish show clinical symptoms, both behavioural and external symptoms. The clinical symptoms of red tilapia attacked by ectoparasites are shown in Figure 1.

Based on Figure 1, infected fish by ectoparasites show clinical symptoms in the form of thin fins, redness of the skin, scales that come off quickly, white spots on the gills, excessive mucus, fungus growth, and loose eyes. Infected fish show changes in behavior, such as appearing weak, decreased appetite, abnormal swimming, and often rubbing their bodies on the pond's surface.

Tilapia infected with ectoparasites exhibit several clinical symptoms. The most notable symptom is the presence of excessive mucus on the gills, which can lead to a pale appearance and a marbling effect on the gill leaflets (Radwan *et al*., 2024). Gill leaflets are thin, branching structures forming aquatic animals' gills, including fish such as tilapia. These leaflets are part of the respiratory system and play a crucial role in gas exchange, allowing the animal to extract oxygen from the water. Each gill leaflet is typically composed of several regions with different epithelial coverings, which facilitate the exchange of gases and the removal of waste products (Klocke *et al*., 2024; Rodriguez *et al*., 2019). Fish attacked by ectoparasites show external symptoms in the form of wounds on the skin surface, the appearance of white spots, thin fins, scales that come off quickly, and excessive mucus production (Iriansyah *et al*., 2020; Pujiasatuti *et al*., 2015). Additionally, the fish may become skinny due to the parasitic burden (Ihsan & Sitinjak, 2023). The severity of the infection can vary significantly, depending on factors such as the types and numbers of infecting ectoparasites, environmental conditions, and fish immunity.

Parasite Identification, Intensity, and Prevalence

Based on the results of examinations of red tilapia at BPTPB Cangkringan and the Cangkringan Market's Pond, five types of ectoparasites were found, including *Trichodina* sp., *Dactylogyrus* sp., *Gyrodactylus* sp., *Ichthyophthirius multifiliis*, and *Oodinium* sp. which can be seen in Table 1.

Based on Table 1, the most common type of parasite found was *Trichodina* sp. *Trichodina* are commonly found in tilapia due to several factors, such as environmental conditions in the Cangkringan market. The tilapia are farmed in crowded conditions, leading to high stocking densities and poor water quality. These conditions favor the proliferation of parasites like *Trichodina*, which thrive in environments with high organic matter and low oxygen levels. Ihsan and Sitinjak (2023) stated that host-parasite relationship and disease transmission influence the occurrence of *Trichodina* in tilapia. Tilapia are naturally euryhaline, which can adapt to various salinity levels. This adaptability makes them susceptible to various parasites, including *Trichodina*, which can infect the gills and skin of the fish. Additionally, *Trichodina* can be easily transmitted from one fish to another through direct contact or contaminated water. Ectoparasites are caused by two factors: internal and external factors. According to Rahayu *et al*. (2013), external factors include cultivation pond water quality, pond water sources, pond sanitation, and cultivation pond stocking density. Internal factors include the level of immunity, gender, age, and body size of the fish. According to Hairunnisa *et al*. (2021), ectoparasites have different specifications to determine the host and target organs to be attacked.

The intensity and prevalence values of ectoparasites found in the BPTPB Cangkringan pond were lower than those found in the Cangkringan Market. The lower ectoparasite infestation in tillapia from BPTPB Cangkringan was due to routine treatments of the fish

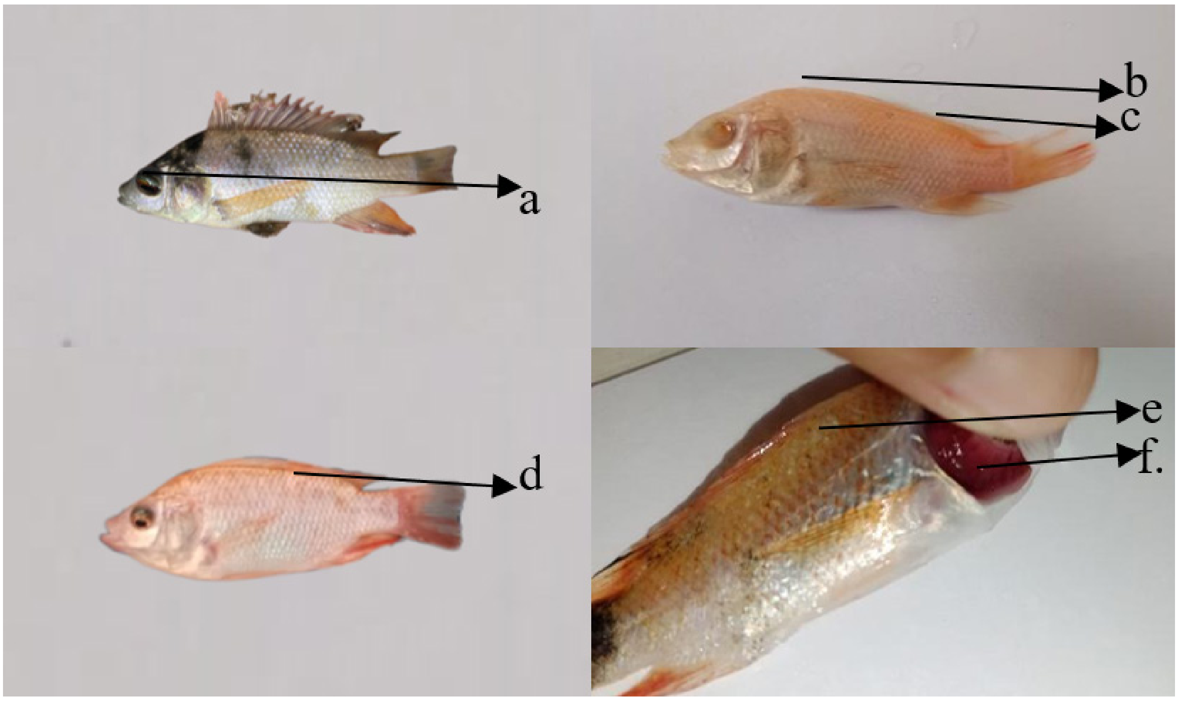

Figure 1. Clinical symptoms of red tilapia attacked by ectoparasites. (a) loose eyes, (b) thin fins, (c) fungus growth, (d) redness of the skin, (e) scales fall off easily, (f) white spots on the gills

Table 1. Species and infestation level of ectoparasites on tilapia derived from the Aquaculture Technology Development Center Cangkringan and the Cangkringan Market's Pond

No.	Parasites	Location	∑ Sample (Ind)	∑ Parasite	∑ Infected Fish	I (Ind.Fish^{-1})	P (%)
1.	*Trichodina* sp.	BPTPB	30	302	20	15.10	66.66
	Dactylogyrus sp.			19	11	1.72	36.66
	Gyrodactylus sp.			25	6	4.16	20.00
	Ichthyophthirius multifiliis			1	1	1.00	3.33
2.	*Trichodina* sp.	Cangkringan Market	5	4589	5	917.80	100.00
	Dactylogyrus sp.			4	2	2.00	40.00
	Gyrodactylus sp.			81	3	27.00	60.00
	Ichthyophthirius multifiliis			8	1	8.00	20.00
	Oodinium sp.			102	4	25.50	80.00

using fermented banana stem to prevent parasitic diseases during the rearing period. In contrast, tilapia from the market did not receive any parasitic treatments. Providing natural ingredients in the form of fermented banana stems in cultivation ponds plays a role in treating disease so that it can reduce the number of ectoparasites that infect fish and impact fish survival. This was confirmed by Sumantriyadi *et al*. (2023), that the provision of natural ingredients with antibacterial or immunostimulant content given to fish can indirectly improve the fish's immune system, thereby increasing fish survival.

Based on observations, *Trichodina* sp. is a round protozoa that moves in circles. *Trichodina* is a genus of ciliate protozoa that are ectocommensal or parasitic on aquatic animals, mainly fish. Body parts of *Trichodina* sp. consist of cilia, border membranes, and denticles. They are characterized by a ring of interlocking cytoskeletal denticles, which support the cell and allow for adhesion to surfaces, including fish tissue. *Trichodina* sp. was found on the skin and gills. Parasite *Trichodina* sp. is in Figure 2.

Trichodina can be round, disc-shaped, or hemispherical. The body shape varies from cylindrical to discoidal, with some species slightly constricted. A spiral of cilia leads towards the cytostome and several rings of cilia at the cell's periphery. These cilia are responsible for creating adhesive suction and locomotory power. The diameter of *Trichodina* ranges from 40-70 μm, with a height of 35-60 μm. The diameter of the denticulate ring can be 29-46 μm, and the diameter of the basal disk can be 42-79 μm. *Trichodina* is typically found on fish's gills, skin, and fins, though some species parasitize the urogenital system. Transmission occurs by direct contact between infected and uninfected hosts and also by active swimming of *Trichodina* from one host to another (Wang *et al.*, 2020).

Morphologically, *Dactylogyrus* sp. is a trematode worm with an elongated body shape. Body parts of *Dactylogyrus* sp. consist of the eye spot (anterior) and opisthaptor (posterior). *Dactylogyrus* sp. was found attacking the gills of fish. *Dactylogyrus* sp. is presented in Figure 3.

Dactylogyrus is a genus of monogenean flatworms that parasitize the gills of fish. The

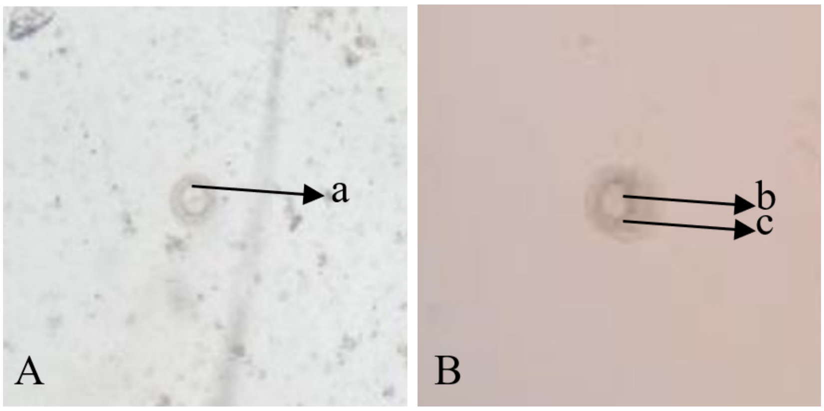

Figure 2. *Trichodina* sp. (A) front view, (B) side view, (a) denticles, (b) border membrane, (c) cilia

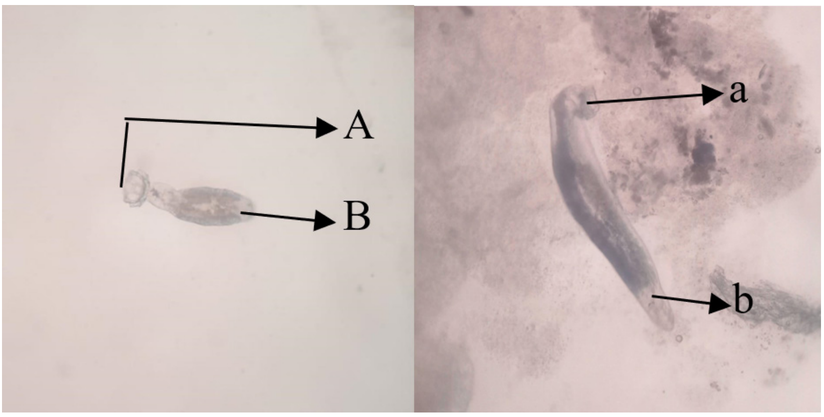

Figure 3. *Dactylogyrus* sp. (A) posterior, (B) anterior, (a) opisthaptor, (b) eye spots

morphology of *Dactylogyrus* includes several key features: *Dactylogyrus* is typically flat and foliaceous, with a small size ranging from 0.5 to 2 mm in length. The anterior end of the worm is characterized by a glandular attachment organ with four cephalic lobes. The posterior end of the worm is simple and lacks any complex attachment structures. The haptor at the posterior end contains anchors, a dorsal bar, and marginal hooks. These structures help the worm attach to the gill arches of its host. *Dactylogyrus* has cilia on its surface, which are used for movement and feeding. The cilia are arranged in a specific pattern that can vary between species (Acosta *et al.*, 2022; Cheng *et al.*, 2023; Jalali *et al.*, 2020).

Gyrodactylus sp. is an ectoparasite of the monogenean worm class that is elongated and transparent in color. The anterior part has no eye spot, and the posterior part has the opisthaptor and marginal hooks. During observations, *Gyrodactylus* sp. was found attacking the scales. The parasite *Gyrodactylus* sp. can be seen in Figure 4.

Gyrodactylus is a genus of monogenean flatworms that parasitize the skin and gills of freshwater fish. *Gyrodactylus* is typically flat and foliaceous, with a small size ranging from 0.5 to 1 mm in length. The anterior end of the worm is characterized by a bilobed cephalic region containing cephalic glands, a pharynx, and an indistinct esophagus. The posterior end of the worm is equipped with a haptor, which includes anchors, a dorsal bar, and marginal hooks. These structures help the worm attach to the host (Chong, 2021; Lumme *et al*., 2017).

Ichthyophthirius multifiliis is a round-shaped ectoparasite of the protozoan class with a C-shaped nucleus called the macronucleus. The body parts of *I. multifiliis* consist of the macronucleus, micronucleus, and cilia (movement organs). *Ichthyophthirius multifiliis*

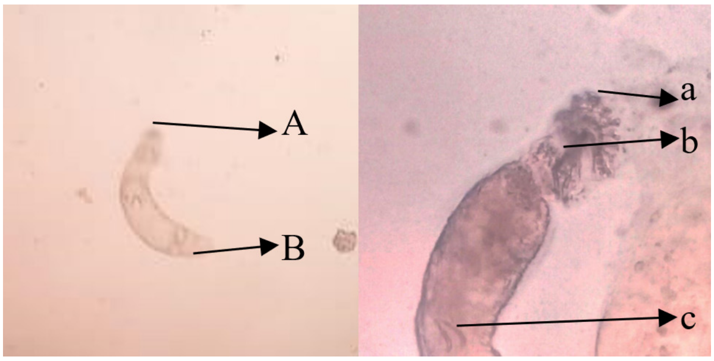

Figure 4. *Gyrodactylus* sp. (A) posterior, (B) anterior, (a) marginal hooks, (b) opisthaptor, (c) vitellaria

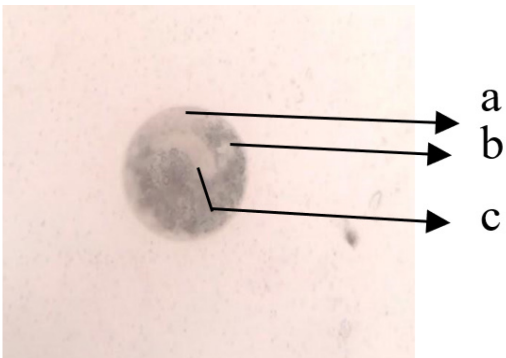

Figure 5. *Ichthyophthirius multifiliis* found in tilapia. (a) cilia, (b) micronucleus, (c) macronucleus

was found attacking the gills. The parasite *I. multifiliis* can be seen in Figure 5.

Ichthyophthirius multifiliis is a parasitic ciliate that infects the skin and gills of freshwater fish. The body of *I. multifiliis* is typically ovoid to spherical, measuring about 5-18 μm in length. The parasite forms cysts during its life cycle, and the cyst wall is composed of a thick, multilayered structure that provides protection and support (Ewing *et al.*, 1983; Yang *et al.*, 2023).

Based on observations, *Oodinium* sp. is an ectoparasite of the protozoan group with a round, slightly oval shape. Body parts of *Oodinium* sp. consist of cytoplasm and protoplasm with a granular structure, nucleus, and chloroplasts. During observations, *Oodinium* sp. was found to infect fish's gills and skin (scales). Ectoparasite *Oodinium* sp. can be seen in Figure 6.

Oodinium sp. is a genus of dinoflagellate parasites that infect the skin and gills of fish. It has an oval or balloon-like shape and typically measures about 5-18 μm in length. The parasite is equipped with rhizoids, which are specialized structures used for attachment. These rhizoids help the parasite adhere to the host's skin and gills (Cheung *et al.*, 1981).

The Duration of Parasite Death

Preparations were made to take ectoparasites found in fish and use them to test their length of death. Table 2 shows the results of banana stem fermentation testing on the length of death of ectoparasites.

The duration of death for ectoparasites given two drops of fermented banana stem ranged from 480-840 s (*Trichodina* sp.), followed by *Dactylogyrus* sp. (1380-1920 s) and *Gyrodactylus* sp. (2040-2640 s), respectively. Treatment C showed the fastest time to kill ectoparasites. The high concentration in treatment C causes this compared to the other two treatments. Based on observations, *Trichodina* sp. was the parasite that died the fastest when given a banana stem fermentation solution, followed by *Dactylogyrus* sp. and *Gyrodactylus* sp. Trichodina is highly sensitive to copper, which is a common ingredient in many antiparasitic treatments. Copper can disrupt the parasite's cell membrane and metabolic processes,

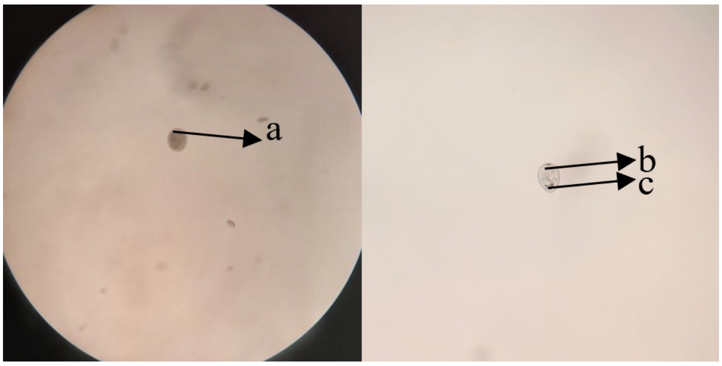

Figure 6. *Oodinium* sp. found in tilapia. (a) protoplasm, (b) cytoplasm, (c) nucleus

Table 2. Effectiveness of banana steam fermentation in the death of ectoparasites found in red tilapia

Treatment	Period of parasite death (s)		
	Trichodina sp.	*Dactylogyrus* sp.	*Gyrodactylus* sp.
A (5 g.L^{-1})	720-840	1800-1920	2520-2640
B (10 g.L^{-1})	660-720	1620-1740	2280-2460
C (15 g.L^{-1})	480-540	1380-1500	2040-2200

leading to rapid death. Besides, *Trichodina* has a direct developmental cycle, meaning it does not require an intermediate host. This simplicity in its life cycle makes it more vulnerable to external factors like bioactive compounds, which can quickly disrupt its life processes. Trichodina does not have a protective coating like other parasites, which can help shield them from bioactive compounds. This lack of protection makes it more vulnerable to the effects of these compounds (Koihealth, 2024; Koitalk, 2023; Smith & Schwarz, 2019). In contrast, *Dactylogyrus* and *Gyrodactylus* have more complex life cycles and attachment mechanisms, which can provide some protection against bioactive compounds. Additionally, their ability to adapt to different environments and hosts might make them more resilient to these compounds.

The effect of ectoparasite death is due to the active ingredients contained in fermented banana stems. The fermentation of banana stems produces a variety of bioactive substances, including alkaloids, flavonoids, tannins, saponins, sterols, triterpenes, vitamins, and phenolic compounds (Afzal *et al*., 2022; Deng *et al*., 2020; Maya, 2015; Pillai *et al*., 2024). Tannin is a secondary metabolite compound that can act as an antigen, antidiarrheal, antibacterial, and antioxidant (Malangngi *et al.*, 2012). Wardani *et al.* (2010) suggested that tannins inhibit enzyme activity and eliminate substrates that bind to lipids and proteins, which are essential for protease enzymes involved in parasite growth. The bioactive compounds contained in the fermented banana stems have antimicrobial and antiparasitic properties, which can help inhibit the growth and activity of ectoparasites in fish. Additionally, fermentation can produce probiotics, beneficial microorganisms that can compete with and displace pathogenic organisms, including ectoparasites. Probiotics can also enhance the fish's immune system, making it more infection-resistant. Ectoparasites in fish can die after the fish soak in a fermented banana stem solution due to several mechanisms: Fermented banana stems contain bioactive compounds such as saponins, flavonoids, alkaloids, and tannins, which have antimicrobial properties. These compounds can inhibit the growth and activity of ectoparasites, such as *Trichodina* and *Dactylogyrus*, by disrupting their cell membranes and metabolic processes. The fermented banana stem solution can improve the fish's health, reducing the susceptibility to ectoparasite infections. Healthy fish are better equipped to resist and recover from parasite infestations (Amalia *et al.*, 2023; Dhema *et al.*, 2022; Fitriani *et al.*, 2022; Suryani *et al.*, 2022).

Survival Rate

Tilapia infected with ectoparasites were taken as test samples. Treatment was carried out using the soaking method of fermented banana stems, which was carried out for 7 days. The survival values of fish treated with fermented banana stems are presented in Figure 7.

The survival rate of fish given banana stem extract ranged from 70-80%; meanwhile, the survival rate of fish without treatment was 50%. The high survival value of tilapia is thought to be due to the active compounds in fermented banana stems. The inhibitory power provided by fermented banana stems will reduce ectoparasite attacks, thereby increasing fish survival. Sinaga (2011) confirmed that plants containing tannins have high antiparasitic levels because tannin compounds can interfere with developing parasite cell walls. The fermentation process can also improve water quality by reducing the levels of organic matter and ammonia, which can create an environment less conducive to the growth of ectoparasites. This improved water quality can further enhance the health and resistance of the fish to ectoparasites (Amalia *et al.*, 2023).

Water Quality

Water quality was assessed by measuring temperature, pH, and DO. The water quality results for the BTBPB and Cangkringan Market ponds are presented in Table 3.

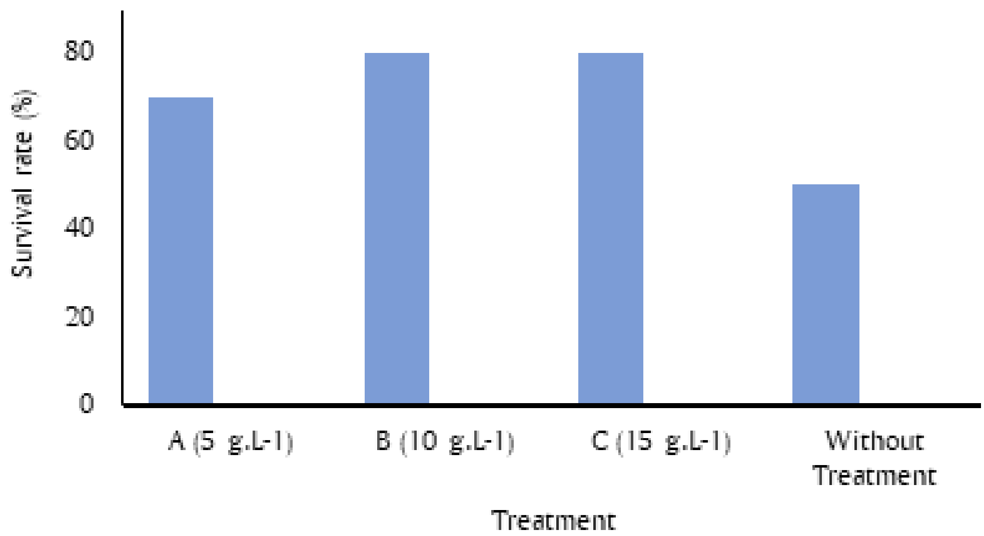

Figure 7. Survival rate of red tilapia treated using fermented banana stems with different concentration

Table 3. Water quality of red tilapia ponds used as sampling units

No.	*Parameter*	*Time*	*Location*		*Standard*
			BTBPB	*Market*	
1.	Temperature (°C)	Morning	23.6-26.9	25.20	25-30 Dailami *et al.* (2021)
		Evening	25.5-27.7	28.50	
2.	pH	Morning	7.68-8.02	7.65	6.5-8.5 Badan Standardisasi Nasional (2009)
		Evening	7.75-8.12	8.22	
3.	DO (mg.L^{-1})	Morning	4.10-7.80	2.00	> 5 Badan Standardisasi Nasional (2009)
		Evening	4.20-8.00	5.00	

Based on the results of water quality measurements in Table 3, the temperature in the morning of the BPTPB Cangkringan pond do not comply with the minimum limits for tilapia. The measurement results at the BPTPB Cangkringan ponds in the morning ranged from 23.6–26.9°C. According to Dailami *et al*. (2021), the optimum temperature for the growth of tilapia is 25–30°C. Temperature has an essential role in the fish growth process. Under these temperature conditions, tilapia cannot grow well. Fish metabolic activity is influenced by water temperature. According to Wangni *et al*. (2019), the higher the water temperature, the more the fish's metabolic processes will increase, whereas at low temperatures, fish tend to lose their appetite and become more susceptible to disease attacks.

The pH value in the BPTPB Cangkringan ponds was 7.68–8.02 (morning), 7.75–8.12 (afternoon), and the Cangkringan Market ponds was 7.65 (morning) and 8.22 (afternoon). The results of measuring the water pH in the BPTPB Cangkringan pond and the Cangkringan Market pond are in a good range for fish growth. According to SNI (2009), the optimal pH for the development of tilapia is 6.5–8.5.

The DO levels in the BPTPB Cangkringan

ponds and Cangkringan Market ponds were 4.1–7.8 mg.L^{-1} (morning), 4.2–8 mg.L^{-1} (afternoon), and 2 mg.L^{-1} (morning) and 5 mg.L^{-1} (afternoon), respectively. DO content < 5 mg.L^{-1} is not an optimal condition for the life of tilapia. According to SNI (2009), the optimal DO content for the life of tilapia is > 5 mg.L$^{-1.}$ Ectoparasites are often more prevalent in environments with low DO levels. Stagnant or poorly oxygenated waters can create conditions that favor the survival and proliferation of ectoparasites. Low DO levels can induce stress in fish, leading to reduced feeding, impaired growth, and a weakened immune response. This makes fish more susceptible to parasitic infections, as their bodies are less capable of fighting off infestations (Ashmawy *et al.*, 2018; Biswas *et al.*, 2023; Waruiru *et al*., 2020).

CONCLUSIONS

The identified parasites infested on red tilapia in this study were: *Trichodina* sp., *Dactylogyrus* sp., *Gyrodactylus* sp., *Ichtyophtirius multifilis*, and *Oodinium* sp. The results showed that the fermented banana stem at concentrations of 10–15 g.L^{-1} significantly accelerated parasite mortality and increased tilapia survival rates by up to 80%. The bioactive compounds in fermented banana stem effectively treat ectoparasites disease attacks and improve fish health.

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AUTHOR CONTRIBUTION

YAS: Conceptualization, Formal Analysis, Investigation, Methodology, Writing – original draft; ECY: Data curation, resources; NRMP: Data curation, Software; NDP: Visualization & Funding acquisition; AFP: Formal analysis; SW: Project administration, Supervision, Writing – review & editing.

DECLARATION OF COMPETING INTEREST

The authors declare no competing interests.

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