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The effectiveness of *Solanum ferox* and *Zingiber zerumbet* extracts on the survival of *Penaeus monodon* in different salinity levels of the cultivation media

Efektivitas ekstrak *Solanum ferox* dan *Zingiber zerumbet* terhadap kelangsungan hidup *Penaeus monodon* pada berbagai tingkat salinitas media budidaya

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ABSTRACT

Decreasing the salinity of the water in the cultivation shrimp disease outbreaks, sluggish development, and mortality. Rainfall, water pollution, and climate change lower salinity. Thus, efforts to enhance tiger shrimp that can survive high salinity changes must be anticipated. This study will examine the effect of adding *Solanum ferox* and *Zingiber zerumbet* extracts to diet to improve tiger shrimp adaption at 10, 15, and 20‰ salinities. *Penaeus monodon* (0.017 ± 0.005 g) were randomly dispersed into nine boxes (1×0.5×0.8 m^3) with 200 shrimp per container and three replicates per group. The shrimp were fed 1:1 extract, *S. ferox* (400 ppm), and *Z. zerumbet* (200 ppm) for 40 days. The study found that adding 5 mL of extract to the feed significantly increases shrimp body weight, weight gain, and specific growth rate at different salinities ($P<0.05$). The difference in salinity remained 100% in all treatments on the 40th day of culture ($P>0.05$). At salinities of 10 and 15‰, the total bacteria and *Vibrio* bacteria in culture media and shrimp were lower than at 20‰ ($P<0.05$). Administration of the extract enhances *P. monodon* adaption at difference salinities. Research suggests that adding 5 mL of a *S. ferox* and *Z. zerumbet* extract to shrimp feed improves growth, survival, and reduces bacteria and *Vibrio* in media and shrimp bodies at salinities of 10-20‰.

Keywords: adaptation, salinities, *Solanum ferox*, tiger shrimp, *Zingiber zerumbet*

ABSTRAK

Penurunan salinitas air media budidaya memicu terjadinya penyakit, perkembangan yang lambat, dan kematian pada udang budidaya. Curah hujan, polusi air, dan perubahan iklim menurunkan salinitas. Oleh karena itu, upaya untuk memperkuat ketahanan udang windu yang dapat hidup dari perubahan salinitas tinggi perlu diantisipasi. Studi ini akan menguji pengaruh penambahan ekstrak *Solanum ferox* dan *Zingiber zerumbet* ke dalam pakan untuk meningkatkan adaptasi udang windu pada salinitas 10, 15, dan 20‰. *Penaeus monodon* (0.017 ± 0.005 g) didistribusikan secara acak ke dalam sembilan kotak container (1×0,5×0.8 m^3) dengan 200 udang per wadah dan tiga ulangan per kelompok. Udang diberi makan ekstrak gabungan *S. ferox* (400 ppm), dan *Z. zerumbet* (200 ppm) perbandingan 1:1, selama 40 hari. Studi ini menghasilkan data, bahwa penambahan 5 mL ekstrak ke pakan secara signifikan meningkatkan berat badan udang, pertambahan berat badan, dan laju pertumbuhan spesifik udang yang dipelihara pada salinitas yang berbeda ($P<0.05$). Perbedaan salinitas tetap menghasilkan kelangsungan hidup 100% pada semua perlakuan pada hari ke-40 budidaya ($P>0.05$). Pada salinitas 10 dan 15‰, jumlah bakteri total dan bakteri *Vibrio* dalam media kultur dan tubuh udang lebih rendah dibandingkan pada salinitas 20‰ ($P<0.05$). Pemberian ekstrak meningkatkan adaptasi *P. monodon* pada berbagai salinitas. Penelitian menunjukkan bahwa penambahan 5 mL ekstrak gabungan *S. ferox* dan *Z. zerumbet* ke pakan udang meningkatkan pertumbuhan, kelangsungan hidup, dan mengurangi total bakteri serta bakteri *Vibrio* dalam media dan tubuh udang yang dipelihara pada salinitas 10-20‰.

Kata kunci: adaptasi, salinitas, *Solanum ferox*, udang windu, *Zingiber zerumbet*

INTRODUCTION

Penaeus monodon is the most widely cultivated type of shrimp in traditional ponds in East Kalimantan (Hardi *et al.,* 2023a; 2023b). The decline in tiger shrimp pond productivity has been caused by many factors, diseases, low growth, and decrease in water quality, especially fluctuating salinity (Ye *et al.,* 2009; Jaffer *et al.,* 2020; Rahi *et al.,* 2021). Water salinity is an important factor for tiger shrimp in ponds, affecting growth and molting cycles, and this is closely related to the success of aquaculture (Brito *et al.,* 2000; Hardi *et al.,* 2023a; 2023b; Jaffer *et al.,* 2020; Liu *et al.,* 2022). Low salinity also prevents the growth of bacteria and can lessen the virulence of diseases like *Vibrio* and WSSV (Naim, 2012).

Tiger shrimp are typically cultured in water with salinities ranging from 20 to 25‰ (Rahi *et al.,* 2021), however the Mahakam Delta waters now have salinities between 8-20‰, and adjusting the water's salinity is a highly challenging procedure because it is tide-dependent. Because of this, efforts must be made to ensure that the seeds of grown tiger shrimp are capable of withstanding a variety of salinities. Raising tiger shrimp at low salinity will have an impact on poor performance (Cui & Chui, 2017), slow growth, immunity, survivability, and overall biological processes (Rahi *et al.,* 2021; Buranajitpirom *et al.,* 2010), which will have an impact on osmotic control (Mugwanya *et al.,* 2022).

The success of the speed of adaptation of tiger shrimp larvae at low salinity is very important for the success of cultivation. Providing feed supplements can help improve health and increase the acceleration of shrimp adaptation. Plant extracts of *Solanum ferox, Zingiber zerumbet*, and *Boesenbergia pandurata* have positive effects on fish health management as prebiotics (Hardi *et al.,* 2022c); adjuvants (Hardi *et al.,* 2019a); antiparasitic (Hardi *et al.,* 2022b); antibacterial (Hardi *et al.,* 2021; 2018a; 2018b; Hardanu, 2022); and immunostimulants for fish (Hardi *et al.,* 2021; 2019b; 2019c; 2018a; 2018b; 2017), white shrimp (Hardi *et al.,* 2022a; Umma *et al.,* 2024), tiger shrimp (Hardi *et al.,* 2022a; 2023a), and crabs (Hardi *et al.,* 2025). In this study, the administration of *S. ferox* and *Z. zerumbet* to tiger shrimp reared at salinities of 10, 15, and 20 ‰ will be tried in an effort to evaluate the growth, survival rate, and bacteria content of tiger shrimp in ponds with water conditions that have a wide range of salinity.

MATERIALS AND METHODS

Experimental Shrimp

Individual juvenile tiger shrimp (0.017 ± 0.005 g) with an average length of 1 ± 0.01 cm, shrimp post larval stage (PL 22), originating from the Manggar fish hatchery, Balikpapan. A total of 2000 juveniles were collected from the hatchery for these shrimp larvae, which were transported in ten different plastic bags (with 200 individuals in each bag) with oxygen provided. The salinity in the transport bag is 20‰ (the same salinity maintained in the hatchery for grow-out).

The shrimp were initially housed in two box (salinity 20‰) with a stocking density of 1,000 in one box that measured 75×45×32 cm^3, and they were given aeration. The shrimp were fed artemia and flakes six times a day during the acclimatization procedure, which lasted seven days. When the shrimp are prepared, they are moved to the maintenance vessel, which is a container tub, to start the aeration process.

Adaptation to differences in salinity media

The shrimp were transferred to a 60×70 cm^2 container, filled with 20‰ of seawater and fresh water from a drilled well. To obtain a treatment medium that is in accordance with the desired salinity, it is diluted with fresh water. Dilution is carried out based on the formula used (Dara *et al.,* 2024) as follows:

$$V1 + M1 = V2 + M2$$

Note:
V = Fresh and sea water volume (L)
M = Initial water salinity (‰)
V2 = Salinity of water after dilution (L)
M2 = Desired salinity (‰)

Tiger shrimp maintenance began with a three days acclimatization phase, followed by a gradual adaptation process that involved gradually lowering the salinity of the seawater in accordance with the therapy. For instance, using the formula, the drop in water salinity from an initial salinity of 15‰ is decreased to 10‰ (Dara *et al.,* 2024). It took five days of salinity reduction before the water in the culture media reached the level of salinity required for the treatment. Prior to the maintenance of tiger shrimp, an acclimatization process was carried out for three hours, then a gradual adaptation process was carried out by steadily lowering the salinity of saltwater according to the treatment.

For example, the decrease in water salinity from an initial salinity of 15‰ is decreased to 10‰ using the formula utilized. The procedure of lowering salinity was carried out for five days until the water in the culture medium had the salinity required by the treatment. The change of water during the acclimation phase is carried out at 25% of the total volume three times a week and is carried out at 07.00 pm, and water quality is checked. Water quality measurements were carried out before the water change at 06.00 pm and the next measurement after the water change was carried out at 06.00 am.

Shrimp feeding

Feeding was given six times delivering as much as 5% of the weight of the shrimp. The meal given is in the form of commercial feed in the form of Fishery Shrimp Flake (TOP®) 40% protein and Artemia (Supreme Plus®). Feeding is done at 07.00 pm, 08.00 pm, 12.00 am, 04.00 am, 06.00 am, and 08.00 am. Artemia feeding was provided at 07.00 pm and 06.00 am. While giving flakes is done every four hours, every morning, evening, and night.

The procedure of blending *S. ferox* and *Z. zerumbet* by enhancing artemia and mixing it with flake feed, prior to feeding the artemia, soak it in 50 mL of *S. ferox* and *Z. zerumbet* solution and then dissolve it in 100 mL of water, and stir until uniformly distributed. Soak the artemia for 30 minutes, then drain it and give it to the shrimp. The flake feed is blended with *S. ferox* and *Z. zerumbet* at a dose of 50 mL, then dissolved in 100 mL of water, swirled until equally distributed, then sprayed on the flake feed using a syringe, air-dried for 15 minutes, and then fed to the shrimp.

Shrimp *Vibrio* bacteria screening

Shrimp larvae that were used in this research were screening *Vibrio* bacteria, and all larvae were free from *Vibrio* sp. detection using the isolation larvae in TCBSA medium and cultured at 37°C for 48 hours for evidence of growth. All shrimp samples must be free from *Vibrio* bacteria.

Experimental

The experimental design used in this study was a completely randomized design (CRD), with each of the three treatments repeated three times. Thus, in this study, there were nine experimental units, and each unit contained 50 shrimp. The treatments in this study were as follows:

P0: Salinity 10‰, with the addition of *S. ferox* and *Z. zerumbe*

P1: Salinity 15‰, with the addition of *S. ferox* and *Z. zerumbet*

P2: Salinity 20‰, with the addition of *S. ferox* and *Z. zerumbet*

A change of water media of as much as 50 % of the total volume is carried out three times a week at 8:00 pm, and air quality control is carried out. Water quality measurements were carried out before the water change at 07.00 am, and the next measurement after the water change was carried out at 05.00 am.

Research parameters

Growth and survival rate

Shrimp weight at the conclusion of the trial and shrimp weight gain served as the study's primary metrics. The following calculating method is based on the formulas developed by Zeynali *et al.* (2020) and Hardi *et al.* (2023a; 2025):

$$WG = Wt - W0$$

$$SGR\ (\%/day) = \left(\frac{(Ln\ W2 - Ln\ W1)}{t}\right) \times 100$$

$$SR\ (\%) = \frac{N_t}{N_0} \times 100\%$$

Note:

Wg = Weight gain (g)
Wt = Final body weight (g)
W0 = Initial body weight (g)
SGR = Specific growth rate
t = Research time (40 days)
SR = Survival rate (%)
Nt = Total final shrimp
N0 = Total initial shrimp

Isolation total bacteria and Vibrio sp.

Each sample from each group research were rinsed thoroughly with sterile distilled water. Alongside the microbial evaluation of the sterile distilled water washing, the washed samples were also assessed for bacterial growth by mutilating, macerating, and smashing into the distilled water. Dilution and plating by spread plate method were carried out soon after sampling. Approximate 15 mL of Plate Count Agar (PCA) for total bacteria and thiosulphate citrate bile salt sucrose (TCBS) Agar for *Vibrio* sp. detection. After inoculation, plates were inverted and placed in incubator at 37°C for 48 hours for evidence of growth. A total six samples have been analyzed in terms of total bacteria and *Vibrio* sp. (Loo *et al.,* 2022).

Water quality monitoring

Water quality factors such as dissolved oxygen, pH, salinity, ammonia (NH_3), nitrate (NO_3), nitrite (NO_2), phosphorus (PO_4), total organic matter, and alkalinity were assessed by The Water Quality Laboratory of the Faculty of Fisheries and Marine Sciences Faculty of Sciences, Mulawarman University, accredited by Indonesia number (KAN) LP-1074-IDN (from February 24, 2021, until December 22, 2025). pengambilan dan preparasi sampel diambil oleh petugas dari Lab. Kualitas Air FPIK UNMUL sesuai dengan SNI : 6964.08:2015. Up until the forty-first day of the year, measurements are made every three days.

Data analysis

One-way analysis of variance (ANOVA) was used to analyze all experiment data, including survival, weight increase, specific growth rate, total bacteria, and total *Vibrio* sp. Duncan's Multiple Range Test was then used to assess differences between treatments.

RESULT AND DISCUSSION

In 40 days, shrimp cultured in different salinity with *S. ferox* and *Z. zerumbet* supplement, were no significant differences (P>0.05) in final weight of shrimp (Figure 2), body weight gain (Figure 3), and specific growth rate (Figure 4). Tiger shrimp

Figure 1. TOP® brand flake shrimp feed.

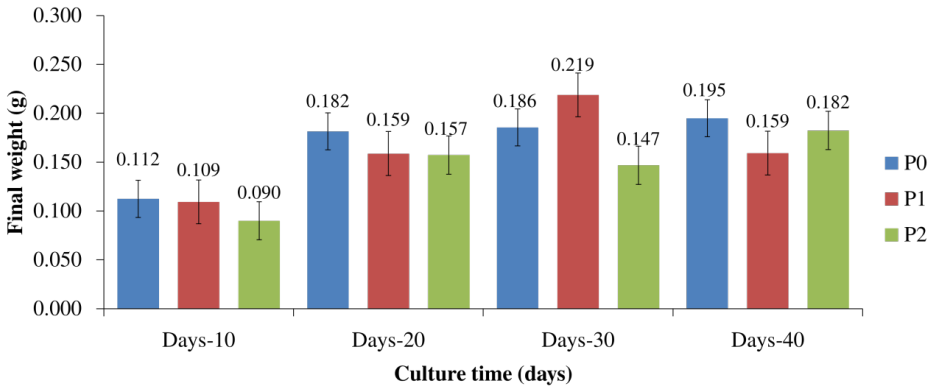

Figure 2. Average final weight of Shrimp culture in different salinity with *S. ferox* and *Z. zerumbet* application.

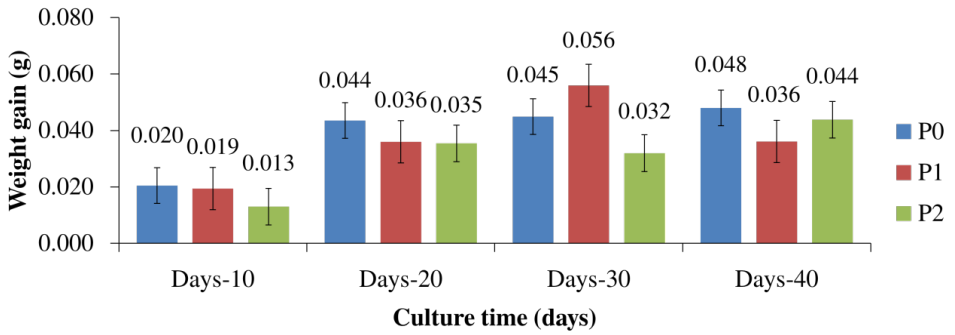

Figure 3. Weight gain of Shrimp culture in different salinity with *S. ferox* and *Z. zerumbet* application.

were grown at 10‰ with the addition of *S. ferox* and *Z. zerumbet*, which resulted in a maximum weight gain (0.048 g) and higher average final weights and weight gains. Similar to daily growth, maintaining at a salinity of 10‰ while applying *S. ferox* and *Z. zerumbet* enhanced tiger shrimp SGR above other salinities; however, maintaining at other salinities while applying *S. ferox* and *Z. zerumbet* had no discernible impact on shrimp growth. Survival rates (Figure 5) of Shrimp larvae cultured in salinities of 10, 15, and 20‰ were 100% and no significantly different (P>0.05).

Examination of total bacteria and total *Vibrio* sp. on shrimp and rearing media was carried out at the beginning and end of the study. The results showed that raising shrimp at a salinity of 10 and 15 ‰ and administering *S. ferox* and *Z. zerumbet* could suppress total bacterial growth (Table 1) in the shrimp's body and was significantly different between salinities 20‰ (P<0.05). As well as the total bacteria in the culture media, maintenance with a different salinity from the application of *S. ferox* and *Z. zerumbet* has a total bacterium (Table 1) that is up to 10^2 CFU/mL in 20‰ salinity. While the bacteria *Vibrio* sp. were not found growing on media or on tiger shrimp.

Discussion

Several studies on the success of raising shrimp at low salinity depend heavily on their health conditions; healthy shrimp have a very fast adaptation ability and only take 3–4 days to get used to living at low salinity (Iber & Kasan, 2021). Research by Gao *et al.* (2016) and Pimentel *et al.* (2024) showed that when *P. vannamei* shrimp were reared at low salinity, only 30% of the

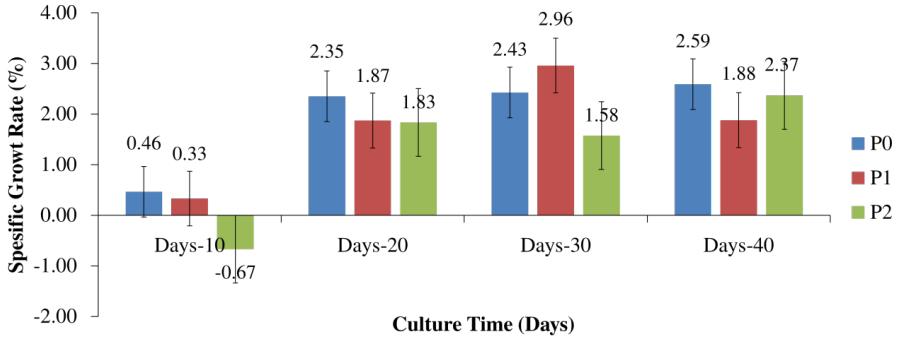

Figure 4. Specific growth rate (%) of shrimp culture in different salinity with *S. ferox* and *Z. zerumbet* application.

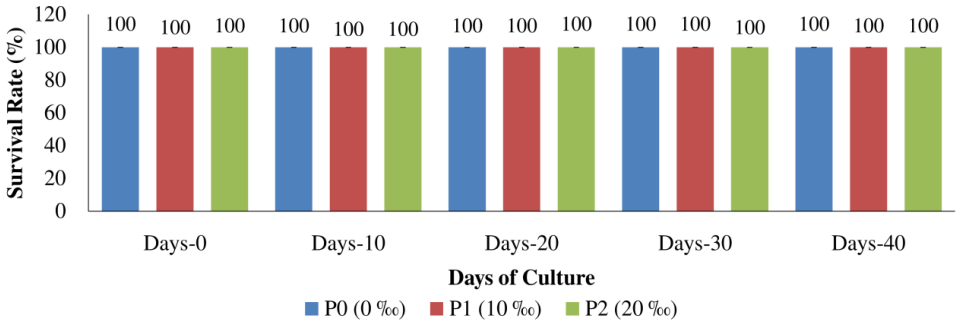

Figure 5. Survival rate of shrimp culture in different salinity with *S. ferox* and *Z. zerumbet* application.

Table 1. Total counts and *Vibrio* sp. detection of shrimp culture in different salinity with *S. ferox* and *Z. Zerumbet* application.

Sample	Shrimp Total count (10^1 CFU/mL)		Water Total count (10^1 CFU/mL)		Shrimp total *Vibrio* sp. (CFU/mL)		Water total *Vibrio* sp. (CFU/mL)	
	D0	D40	D0	D40	D0	D40	D0	D40
P0	2.02 ± 0.1[a]	11.0 ± 0.1[a]	1.00 ± 0.1[a]	230 ± 0.1[b]	No	No	No	No
P1	2.01 ± 0.1[a]	11.5 ± 0.2[a]	1.30 ± 0.1[a]	280 ± 0.2[b]	No	No	No	No
P2	2.02 ± 0.3[a]	13.0 ± 0.3[b]	1.20 ± 0.2[a]	350 ± 0.1[c]	No	No	No	No

Note: No, not growth.

shrimp could survive. Silva *et al.* (2022) stated that tiger shrimp reared at a salinity of 5–10‰ had a survival rate of 50%. Pimentel *et al.* (2024) further explained that *L. vannamei* shrimp can live 100% at a salinity of 5‰ through a gradual acclimation procedure.

The adaptation process of moving to low salinity is a determining factor for success. The adjustment in salinity in this study was carried out in stages within seven days by reducing the salinity of seawater from 25‰ to 10, 15, and 20‰, resulting in a high survival rate of 100%. This process of gradual reduction in salinity provides enough time for the shrimp to be able to change the ionic concentration of the body to reach a stable condition (Pimentel *et al.,* 2024). In this study, tiger shrimp reared at a salinity of 10–20‰ with the addition of *S. ferox* and *Z. zerumbet* survived 100%. The gradual acclimatization process and administration of immunostimulants were a combination of stages that made this research successful.

Valencia-Castañeda *et al.* (2019) study observed an increase in the survival of the same species after an acclimation period of 72 hours. The gradual acclimatization process and administration of *S. ferox* and *Z. zerumbet* are the main factors in the 100% survival of these tiger

Table 2. Water quality of shrimp culture.

Variable	Groups	Range value*
Temperature (°C)	P0	26.00-30.00
	P1	26.50-30.00
	P2	26.00-30.00
Dissolved Oxygen (mg/L)	P0	3.98-5.34
	P1	3.35-4.48
	P2	3.35-5.00
pH	P0	6.12-8.99
	P1	6.55-7.38
	P2	7.87-8.88
Salinity (‰)	P0	10.00
	P1	15.00
	P2	20.00
Ammonia (NH3) (mg/L)	P0	0.20-0.30
	P1	0.22-0.40
	P2	0.20-0.50
Nitrate (NO3) (mg/L)	P0	0.10-0.20
	P1	0.10-0.20
	P2	0.10-0.30
Nitrite (NO2) (mg/L)	P0	0.10-0.20
	P1	0.05-0.10
	P2	0.05-0.10
Phosphate (PO4) (mg/L)	P0	0.10-0.50
	P1	0.10-0.50
	P2	0.10-0.60
Total Organic Matter (mg/L)	P0	20.00-30.00
	P1	15.00-28.00
	P2	20.00-35.00
Alkalinity (mg/L)	P0	66.00-120.0
	P1	78.00-120.0
	P2	80.00-120.0

Reference: * Ndunguru *et al.* (2022).

shrimp. In addition to reducing the influence of factors other than salinity and *S. ferox* and *Z. zerumbet*, this study implemented water changes taking into account the salinity in the rearing container so that water quality suitable for tiger shrimp was obtained (Rahi *et al.,* 2021; Golder *et al.,* 2022). Water quality includes DO 3-5 mg/L, recommended Alkalinity ≥100 mg/L, and in this treatment range, 66–120 mg/L (Pantjara *et al.,* 2024), and overall water quality in all cultivation media at a salinity of 10, 15, and 20‰ have appropriate ranges for tiger prawn cultivation.

Rahi *et al.* (2021) once reviewed that tiger shrimp reared at a salinity of <20‰ experienced a slowdown in growth, the number of deaths increased, and their susceptibility to infection increased, but this did not happen in this study, the average individual weight of *P. monodon* was reared at salinities of 10, 15, 20 ppt did not experience a difference in growth ($P<0.05$). This indicated that at low salinities <20‰ the shrimp could still grow well, administration of *S. ferox* and *Z. zerumbet* helped increase the immune system so that the shrimp were in healthy condition, physiologically stable, shrimp appetite is normal, metabolism is stable so growth remains good (Moshtaghi *et al.,* 2018; Yilmaz and Goluch, 2021). Rearing at low salinity has beneficial effects in aquaculture, including breaking the chain of development of pathogens that usually attack shrimp, reducing the speed of growth of pathogens, and reducing the virulence of pathogens, so that actually rearing tiger shrimp at a salinity of <20‰ can be a solution to disease problems (Deris *et al.,* 2020). Several species of shrimp, *Panaeus* sp., can adapt well to low salinity: *P. vannamei, P. californiensis, P. brevirostris*, and *P. stylirostris* (Ye *et al.,* 2023).

Maintenance at low salinity is actually believed to be a solution for tiger shrimp cultivation in ponds in the face of climate change, which causes fluctuations in water quality. Administration of plant extract as an immunomodulator is also effective in increasing the success of shrimp farming. *S. ferox* and *Z. zerumbet* been reported to increase the immune system of fish (Hardi *et al.,* 2021; 2018; 2019a,b,c; 2023), vannamei shrimp (Umma *et al.,* 2024), and tiger shrimp (Hardi *et al.,* 2022a). The results of this study showed that the difference in salinity of 5‰ did not show any significant difference in the growth and survival rate of tiger shrimp. The administration of *S. ferox* and *Z. zerumbet* helped increase shrimp adaptation while increasing growth, so that shrimp growth remained good even though the media salinity was low.

Research on tiger shrimp showed that *S. ferox* and *Z. zerumbet* was able to suppress *Vibrio* sp. (Hardanu, 2022) and increase the total number of hemoglobin in tiger shrimp (Hardi *et al.,* 2022a). Furthermore, Ye *et al.* (2009) and Reiser *et al.* (2017) reported that the growth of tiger shrimp was better in seawater with a salinity of >25‰, this was a factor in decreasing pond productivity due to a decrease in seawater salinity due to climate change. However, in this study, growth and survival did not differ at low and high salinities. Shrimp growth at low salinity is slower than that at ideal salinity. Additional research indicates that an isoosmotic environment substantially influences digestion and growth in fish (Faulana & Rohmah, 2025). Taqwa *et al.* (2011) stated that post larvae of Pacific white shrimp (*Litopenaeus vannamei*) cultivated in low salinity necessitate additional feed with enhanced protein to promote growth.

Another study showed that monodons survived and grew better when the salinity was over 20‰, but they did not test yields below 20‰ (Valencia-Castañeda *et al.,* 2019). Based on the findings of this study, it appears that low salinity does not seem to affect osmotic regulation as far as growth and survival rates in tiger shrimp are concerned. tiger shrimp growth in low-saline waters shows that salinity is not the only limiting factor for its growth. Although some researchers explain how salinity will affect growth and survival, lower salinity affects physiological stress because most of the shrimp's energy is used in osmoregulation, limiting growth and preventing them from reaching commercial size.

CONCLUSION

The research results show that the average number of bacteria in the media and tiger shrimp is lower, and no *Vibrio* sp. are found growing. Shrimp growth and survival rate were stable in a 5‰ fluctuation salinity medium. This shows that the secondary metabolites of the extract are able to suppress bacterial growth, and the extracts of *S. ferox* and *Z. zerumbet* can help improve the adaptation of shrimp to live in a salinity range of 5‰. Both extracts have the potential to be used in the cultivation of *P. monodon* culture in ponds with salinity fluctuations ranging from 10 to 20‰.

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