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Light Spectrum Manipulation Enhances Growth and Survival in Early Juvenile Seabass (*Lates calcarifer*)

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ABSTRACT

Seabass (*Lates calcarifer*) is a fish with high economic value and great demand in the community, making it a promising species for continued development. The seabass has diurnal habits, meaning it will be active during the day or when exposed to light. Environmental manipulation techniques can improve fish growth and survival by regulating light intensity. It is suspected that exposure to blue light can positively affect growth and survival and can optimize physiological responses compared to other colored light treatments. This research was conducted at the Fisheries and Marine Resources Exploitation Laboratory, Faculty of Fisheries and Marine Sciences, Brawijaya University, from January to February 2024. The method used was a Completely Randomized Design (CRD), with three different light color treatments: red, blue, and green. The observed parameters are Specific Growth Rate (SGR), Survival Rate (SR), and Water Quality. The results show that blue light treatment significantly affects the growth and survival of seabass juveniles. The highest Specific Growth Rate for weight was recorded at 29±0.09% and for length at 32±0.04%, with a survival rate of 100%. The administration of blue light treatment was found to support the physiological and feeding behavior of the fish optimally. Meanwhile, red and green light treatments showed lower performance in Specific Growth Rate of weight, with 22 ± 0.05% and 18 ± 0.15% respectively. For the Specific Growth Rate (SGR)of length, the red color treatment was 30 ± 0.07%, the green color was 22 ± 0.05%, and the survival rate (SR) for red light treatment was 93% and the green color was 80%. Based on these results, blue lighting is recommended as an environmental management strategy to improve the productivity of seabass juveniles in the early maintenance phase.

INTRODUCTION

Seabass (*Lates calcarifer*), commonly called Barramundi, is a commercially important species widely distributed across the Western Indo-Pacific region, extending from Southeast Asia to Papua New Guinea and Northern Australia. This species exhibits diurnal and demersal behavior, being predominantly active during daylight hours or under illuminated conditions **(Wirasakti *et al*., 2021)**. As an euryhaline species, Seabass can thrive and reproduce in both freshwater and marine environments, making it highly adaptable for diverse aquaculture systems **(Vij *et al*., 2020; Santika *et al*., 2021)**. In Indonesia, production in 2020 reached 492,267 metric tons, while market demand was estimated at 522,267 metric tons, indicating a significant production gap and highlighting the potential for expansion of Seabass aquaculture. In addition to Indonesia, Seabass is also cultured in several other Asian countries, including Thailand, Malaysia, Singapore, Hong Kong, and Taiwan, as well as in non-Asian regions such as the United States and Australia **(Kusumanti *et al*., 2022)**.

The aquaculture of Seabass (*Lates calcarifer*) comprises three main phases: hatchery, nursery, and grow-out **(Gilsinan *et al*., 2023)**. The success of the entire production cycle is strongly influenced by the consistent supply of high-quality and sufficient juvenile stock **(Pape & Bonhommeau, 2013; Moehammad *et al*., 2024)**. The nursery phase represents a critical period during which fish are highly susceptible to parasitic infections that can lead to tissue damage and organ dysfunction, underscoring the importance of early health management. High mortality during this stage can significantly reduce overall production yields, as survival rates directly determine output. Juvenile mortality is particularly concerning due to the immature immune systems of young fish and their vulnerability before reaching reproductive maturity **(Daulay *et al*., 2022; Kurniawan *et al*., 2025)**. Survival during the nursery phase is influenced by several key factors, including the absence of intra-species competition, adequate feed availability, uniform stocking densities, and consistent fish size distribution **(Eid *et al*., 2019; Nazlia *et al*., 2021)**.

One critical component in managing the nursery phase in aquaculture is the manipulation of environmental conditions in which fish are reared. Environmental manipulation techniques have been shown to enhance growth performance and survival rates by regulating light intensity **(Boeuf *et al*., 1999)**. Fish species exhibit varying degrees of phototactic responses, and specific light intensities and wavelengths can directly or indirectly influence their behavior. Some species demonstrate adaptive responses to low-light environments, while others are better suited to brighter conditions **(Boeuf *et al*., 1999; Garcia *et al*., 2011)**. Light manipulation technologies are recognized as effective tools for inducing physiological responses in fish by modifying the spectral quality (wavelength), quantity (intensity), and periodicity (photoperiod) of light exposure **(Gunawan *et al*., 2022)**.

Therefore, this study was designed to evaluate the effect of different light spectra on the growth performance and survival rate of juvenile Seabass (*Lates calcarifer*). It is hypothesized that exposure to blue light will promote superior growth and survival compared to red and green light treatments. This hypothesis is supported by previous studies indicating that blue light can positively influence fish growth by stimulating feeding behavior and optimizing physiological responses **(Kaewpranee *et al*., 2022; Sabrina *et al*., 2023)**.

MATERIALS AND METHODS

Sample

A total of forty-five (45) Seabass (*Lates calcarifer*) juveniles, with an average initial weight of 7.26 ± 0.40 grams and a length of 7.84 ± 0.02 cm, were obtained from the Balai Perikanan Budidaya Air Payau (BPBAP), Situbondo, East Java, Indonesia. Fish were fed a commercial diet (Megami GR-2) at a feeding rate of 3% of their body weight per day. The research was conducted at the Fisheries and Marine Resources Exploitation Laboratory, Faculty of Fisheries and Marine Sciences, Brawijaya University, from January to February 2024.

Experimental design

This study employed a completely randomized design (CRD) consisting of three different light color treatments (red, blue, and green), each replicated three times, resulting in nine experimental units. The stocking density was set at five fish per container, and a Recirculating Aquaculture System (RAS) was used throughout the experiment. Three distinct light colors—red, blue, and green—were applied using 6-watt tube light (TL) lamps, each emitting 500 lumens and measuring 30 cm in length. Fish were reared in 30-liter capacity containers with dimensions of 45.8 × 33.2 × 26 cm. Each container was externally covered with a black shield to minimize ambient light interference.

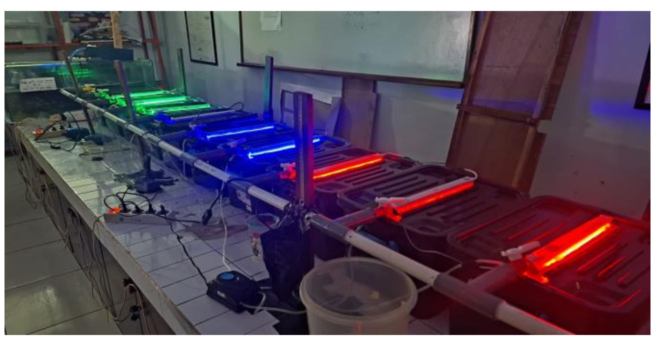


Fig. 1. Containers used for the light color treatment experiment on Seabass juveniles

Research procedure

The juvenile Seabass (*Lates calcarifer*) were maintained in black-colored containers with a capacity of 30 liters (dimensions: 45.8 × 33.2 × 26 cm) under a water salinity of 30 ppt, which was monitored using a refractometer. The Recirculating Aquaculture System

(RAS) was equipped with a filtration system consisting of dacron, bioballs, and zeolite stones. Water circulation was ensured using a pump (SUNSUN JTP 10000 PROPAM). The fish were cultured for 21 days, with a stocking density of five individuals per container. Fish length and weight measurements were taken on days 0, 7, 14, and 21 using a ruler and an electronic scale with a 0.01 g resolution (brand: Synmore). Manual siphoning of waste and uneaten feed was performed daily at 07:00 AM to maintain optimal water quality.

Light distribution measurements were conducted using a Luxmeter (TASI TA8133) at designated points along the x, y, and z axes. The x-axis represented the container's width, the y-axis denoted the water depth, and the z-axis corresponded to the light intensity values recorded at each measurement point. Each point was spaced 10 cm apart. The collected data were processed and visualized using Surfer 10 software.

Data analysis

The parameters analyzed in this study included specific growth rate, survival rate, feed conversion ratio, and water quality metrics. Blood glucose and cortisol levels were first tested for normality using the Shapiro-Wilk test and for homogeneity using Levene's test. Subsequently, data were analyzed using a one-way analysis of variance (ANOVA) at a significance level of $P < 0.05$. Meanwhile, water quality parameters and light intensity distribution were analyzed descriptively. All statistical analyses were conducted using SPSS version 23.

Parameters observed

1. Specific growth rate (SGR)

Growth performance was evaluated using the Specific Growth Rate (SGR), which quantifies the rate of increase in body weight or length over time. The SGR was calculated using the formula from **(Islama *et al*., 2023)**:

$$SGR = [(\ln Wt - \ln W0) / t] \times 100\%$$

Where:

- **SGR** = Specific Growth Rate
- **Wt** = Total weight or length at the end of the study
- **W0** = Initial weight or length at the beginning of the study
- **t** = Duration of the experiment (days)

2. Survival rate (SR)

Survival performance was assessed using the Survival Rate (SR), representing the percentage of individuals that remained alive throughout the experimental period. The SR was calculated using the formula from **(Dauda *et al*., 2018)**:

$$SR (\%) = (Nt / N0) \times 100\%$$

Where:

- **SR** = Survival Rate (%)

- **Nt** = Number of fish at the end of the study
- **N0** = Number of fish at the beginning of the study

3. Water quality

Water quality was monitored daily in the morning for parameters including temperature, salinity, pH, and dissolved oxygen (DO). Ammonia levels were measured on days 0, 7, 14, and 21 of the rearing period. The assessment was conducted based on the Indonesian National Standard (SNI 6145.3:2014) for Seabass (*Lates calcarifer*) aquaculture. The instruments used for each water quality parameter are summarized in Table (1).

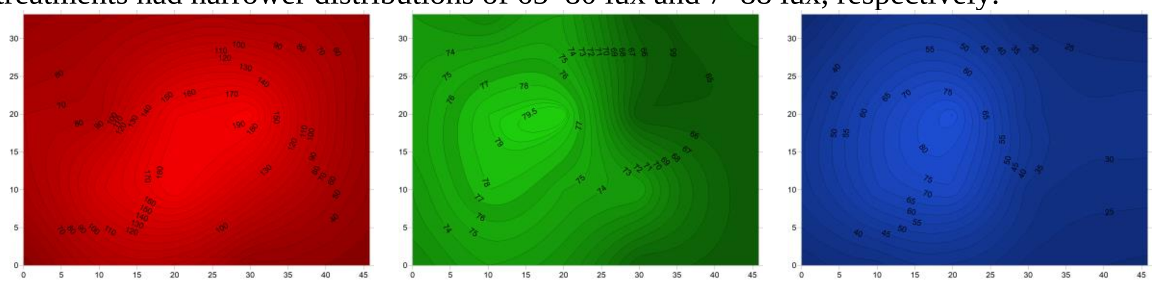
Table 1. Instruments used for water quality parameter measurements during the 21-day rearing period of Seabass (*Lates calcarifer*) juveniles

Parameter	**Instrument**
pH	Lutron YK-2001 PHA
Dissolved Oxygen (DO)	Lutron YK-2001 PHA
Temperature (°C)	Lutron YK-2001 PHA
Ammonia (ppm)	Ammonia Test Kit (Brand MONITOR)

RESULTS

1. Light distribution on container

Light distribution analysis was conducted to determine how much light intensity could disperse throughout the rearing container. The results (Fig. 1) showed that the red light treatment exhibited a distribution range of 7–185 lux, while the green and blue light treatments had narrower distributions of 65–80 lux and 7–88 lux, respectively.



Red Lamp Green Lamp Blue Lamp

Fig. 2. Spatial light intensity distribution in containers exposed to red, green, and blue LED lights. The contour maps display variations in light intensity across the rearing containers, where the x- and y-axis represent the container's length and width (in cm), respectively. Light intensity ranged from 7–185 lux in the red light treatment, 65–80 lux under green light, and 7–88 lux under blue light. Each color treatment produced distinct spatial illumination patterns, potentially influencing fish behavior and growth performance through differential light exposure

2. Specific growth rate

The specific growth rate (SGR) based on body weight over the 21-day rearing period (Fig. 3) was highest in the blue light treatment, with a value of 29 ± 0.09%, followed by the red light treatment at 22 ± 0.05%, and the green light treatment at 18 ± 0.15%. Similarly, the specific growth rate based on length over the same period (Fig. 2) was also highest under blue light at 32 ± 0.04%, followed by red light at 30 ± 0.07%, and green light at 22 ± 0.05%.

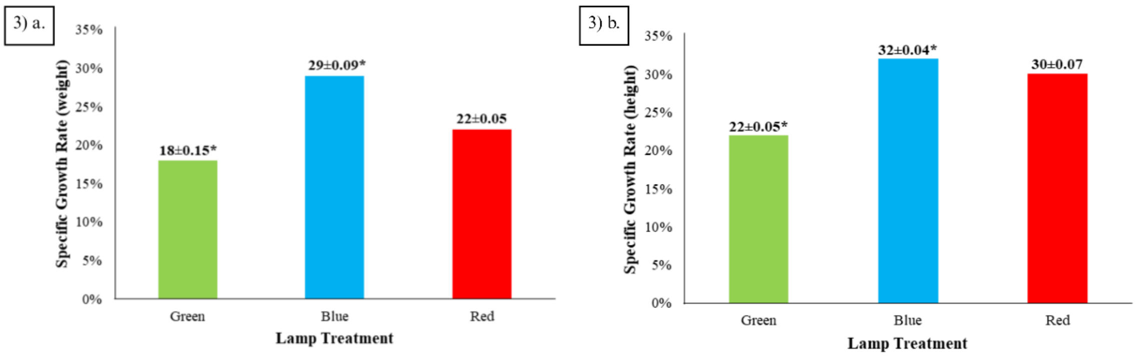


Fig. 3. Specific growth rate (SGR) (%) by a. weight and; b. length of seabass (*Lates calcarifer*) juveniles under red, green, and blue light treatments

Table 2. Specific Growth Rate (SGR) weight and length of Seabass (*Lates calcarifer*) juveniles reared under different LED light colors for 21 days

		Treatment Lamp			**F-value (statistic)**	**F-table**	**Sig.**
		Green	**Blue**	**Red**			
Specific Growth Rate	**Weight**	22±0.05*	32±0.04*	30±0.07	4.56	3.40	0.021
	Height	18±0.15*	29±0.09*	22±0.05	3.53	3.40	0.045

Data are presented as mean ± standard error (n = 3). Asterisks (*) indicate statistically significant differences among treatments based on the LSD post hoc test at $P < 0.05$.

Based on the analysis of variance (ANOVA) results (Table 2), the application of different LED light colors had a statistically significant effect on the Specific Growth Rate (SGR), both in terms of body weight and length of juvenile Seabass (*Lates calcarifer*) during the 21-day rearing period ($P < 0.05$). The calculated F-values for body weight (4.56) and length (3.53) exceeded the critical F-table value (3.40), indicating significant differences among the light treatments.

Post hoc LSD analysis revealed that the blue light treatment significantly outperformed the other treatments in both weight and length parameters. Asterisks (*) on the mean SGR values for body weight (32 ± 0.04) and length (29 ± 0.09) under the blue light condition denote statistically significant differences compared to the green and red light treatments. In contrast, no significant differences were observed between the green and red light treatments, as indicated by the absence of asterisks on their respective mean values.

These findings suggest that blue spectrum light more effectively stimulates somatic growth and elongation in juvenile Seabass than red and green light. Therefore, blue lighting can be recommended as an optimal illumination strategy to enhance growth performance during the early rearing phase in intensive aquaculture systems.

3. Survival rate

The survival rate of Seabass juveniles (Fig. 4) was highest under the blue light treatment, reaching 100%, followed by 93% under red light and 80% under green light. Mortality occurred in one fish under the red light treatment and in four fish under green light.

One of the primary contributing factors to mortality was elevated ammonia concentration. In this study, ammonia levels ranged from 0.25 to 0.5 mg/L, which exceeded the maximum threshold of 0.1 mg/L for juvenile Seabass culture, as specified by the Indonesian National Standard (SNI 6145.3:2014) for water quality parameters.

However, the analysis of variance (ANOVA) indicated that the application of different light color treatments did not result in a statistically significant effect on the survival rate of Seabass juveniles ($P > 0.05$).

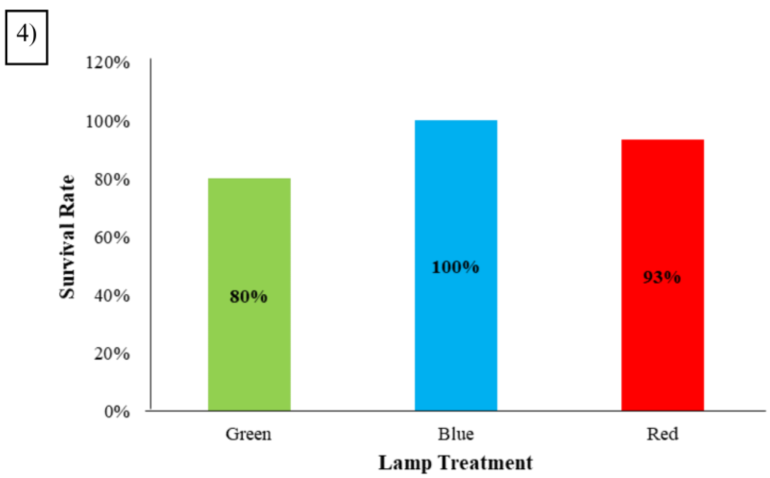


Fig. 4. SR (%) by weight and length of Seabass (*Lates calcarifer*) juveniles under red, green, and blue light treatments

3. Water quality

To ensure optimal rearing conditions, water quality measurements were conducted to assess key parameters, including temperature, pH, dissolved oxygen (DO), and ammonia. The results of water quality monitoring over the 21-day rearing period for juvenile Seabass exposed to green, blue, and red light treatments are summarized in Table (3). According to the Indonesian National Standard for Seabass aquaculture (SNI 6145.3:2014), the recorded temperatures ranged between 27.6°C and 28.8°C, pH values ranged from 7.7 to 8.0, and DO concentrations ranged from 6.2 to 7.3 mg/L across all treatments—indicating that these parameters remained within the optimal range for juvenile Seabass rearing.

However, ammonia levels exceeded the recommended maximum threshold, reaching concentrations of up to 0.5 ppm. This is considered critically high and potentially harmful to the health and survival of juvenile Seabass, posing a risk of stress, immunosuppression, and mortality if not properly managed.

Table 3. Physicochemical water quality parameters in seabass (*Lates calcarifer*) juveniles rearing tanks under different light treatments over 21 days, compared to the Indonesian National Standard (SNI 6145.3:2014)

Parameter	Treatment Lamp			SNI 6145.3:2014
	Green	Blue	Red	
Suhu (°C)	27.5-28.6°C	27.5-28.7°C	27.6-28.8°C	26-32°C
pH	7.7-8	7.7-8	7.7-8	7.0-8.5
DO (mg/L)	6.2-6.6	6.3-6.9	6.5-7.3	>4 mg/L
Ammonia (NH3)	0.25-0.5	0.25-0.5	0.25-0.5	<0.1 ppm

DISCUSSION

The Specific Growth Rate (SGR) of Seabass (*Lates calcarifer*) juveniles over a 21-day rearing period showed the most optimal results under the blue light treatment, with a weight-specific growth rate of 29% and a length-specific growth rate of 32%. This reinforces that the blue light spectrum significantly stimulates somatic growth and biomass accumulation during the juvenile stage. The absence of mortality in the blue light treatment further highlights that environmental conditions under this spectrum effectively support the fish's physiological functions and feeding behavior. Blue light intensity ranged from 7–88 lux, still within the tolerance range for the growth of various marine fish species. Although **Boeuf *et al*. (1999)** reported that *Sparus auratus* larvae grow optimally at 50–150 lux, the positive growth observed at lower intensities suggests a specific adaptation in Seabass juveniles. According to **Barahona-Fernandez (1979)**, Seabass is a diurnal species highly dependent on lighting for feeding activity. Improved visual acuity under blue light likely enhanced feed intake and resulted in a superior Feed Conversion Ratio (FCR) of 0.70, outperforming the red and green light treatments.

The strong relationship between light and growth is supported by **Boeuf *et al*. (1999)**, who emphasized that light spectrum and photoperiod affect growth by influencing feed metabolism, not just intake. Blue light, due to its shorter wavelength, penetrates deeper into the water column and increases the visibility of feed particles. This makes it an effective spectrum for stimulating active feeding. Supporting this, **Nurdin *et al*. (2015)** demonstrated that blue LEDs significantly improved growth rates in Silver

Carp (*Barbonymus gonionotus*), attributed to enhanced feed recognition. Likewise, **Gunawan *et al*. (2022)** reported that blue LED lighting yielded the best growth in Gourami (*Osphronemus gouramy*) larvae. Similar findings were recorded by **Novita *et al*. (2019)** in clownfish, where blue light resulted in the highest SGR. These cross-species studies suggest consistency in the efficacy of blue light. According to **Wirasakti *et al*. (2021)**, the interaction of media color and light affects a fish's ability to locate feed. Under blue lighting, feed particles have higher contrast against the background, improving foraging efficiency. Furthermore, **Sánchez-Vázquez *et al*. (2019)** found that combining blue light with a controlled light-dark cycle improved growth and hatch rates in *Dicentrarchus labrax* and *Solea senegalensis*, demonstrating that spectrum, intensity, and photoperiod are all critical for regulating fish biological rhythms.

Light color also significantly influences hormonal responses, particularly melatonin and cortisol secretion, which impact feeding behavior and stress responses. For instance, **Bayarri *et al*. (2002)** showed that blue light more effectively modulated plasma melatonin levels than red light in Seabass, playing a key role in circadian rhythm regulation and stress reduction. Similarly, light wavelength influenced stress responses in juvenile red sea bream **(Kawamura *et al*., 2017)**, highlighting light's effect on hormonal balance. Maintaining optimal light environments supports fish health by regulating cortisol levels—a widely recognized indicator of stress **(Dopeikar *et al*., 2024)**. Elevated cortisol is associated with suppressed feeding motivation and growth performance **(Templonuevo & Cruz, 2016)**. Additionally, different light spectra can influence the hypothalamic–pituitary–interrenal (HPI) axis, which modulates cortisol production and physiological responses **(Azarin *et al*., 2014)**. Prolonged stress elevates cortisol levels, impairing growth and digestion **(Volpato *et al*., 2013)**.

Environmental light also affects phototactic behavior. For example, **Almaas and Harlita (2023)** found that light color altered growth and foraging behavior in guppies. On the other hand, **Tsounis and Kehayias (2021)** showed that optimal light improved feeding, reduced predation risk, and enhanced reproduction. Furthermore, specific light spectra influence endocrine responses. Blue light stimulated higher expression of growth hormone (GH) in yellowtail clownfish compared to red light **(Kim *et al*., 2016)**. Similarly, increased light intensity (915 lux) was linked to better feeding and growth in larval fish via endocrine stimulation **(Nwosu & Holzlöhner, 2000)**.

In red hybrid tilapia, light and tank color influenced digestive enzyme activity and feed utilization efficiency **(El-Dakar *et al*., 2023)**. Efficient enzymatic performance under optimal lighting improves nutrient absorption, leading to better weight gain and FCR. Specific light wavelengths may activate enzymes crucial for digestion, emphasizing light's broader physiological role.

The highest survival rate of juvenile Seabass was recorded under blue light (100%), followed by red (93%) and green (80%) treatments. This supports findings by **Sánchez-Vázquez *et al*. (2019)**, who reported that blue light-dark cycles produced the highest survival and feed intake compared to other wavelengths. One fish died under red light, while four died under green. The high mortality in green-treated tanks is attributed to elevated ammonia levels (0.25–0.5 mg/L), exceeding the optimal threshold of 0.1 mg/L defined by SNI 6145.3:2014. **Negesse (2018)** also confirmed that poor water quality, including high ammonia, significantly impacts fish growth and survival.

Ammonia negatively affects fish through various mechanisms, such as gill impairment and ion regulation disruption **(Roumieh *et al*., 2012; Zou *et al*., 2023)**. Toxic ammonia levels suppress growth and feeding efficiency in species like juvenile yellow catfish and goldfish **(Yang *et al*., 2011; Zhang *et al*., 2016)**. In Wuchang bream, ammonia exposure disrupted the GH/IGF axis, directly impeding growth **(Guo *et al*., 2021)**. Stress-induced appetite loss due to ammonia has also been reported **(Uchenna *et al*., 2022)**. Infected or stressed fish commonly exhibit reduced appetite, body discoloration, or ulceration **(Kungvankij *et al*., 1986; Susanti *et al*., 2022)**. Deceased individuals showed signs such as blackened skin, body ulcers, and severely eroded tail fins (Fig. 5), consistent with *Vibrio vulnificus* infection as noted by **Zaenuddin (2019)** (Fig. 6).

Beyond light, water quality directly influences fish growth. Temperature fluctuations observed weekly across treatments were likely caused by ambient conditions and flow from the filtration system. Despite using 25-watt heaters set to 29°C, incoming water lowered actual temperatures. As a critical metabolic factor, temperature variation must be minimized to ensure consistent growth. DO levels varied significantly, particularly in the red light treatment, likely due to that container's proximity to the filter inlet, increasing water flow and destabilizing oxygen levels. This underscores the need to properly position containers within the RAS to maintain water quality consistency.

Other parameters such as pH, salinity, and ammonia remained relatively stable across treatments due to the RAS setup, which allowed filtered water to be evenly recirculated. RAS systems promote uniformity in water parameters **(Khan *et al*., 2022)** but are still susceptible to waste accumulation **(Piranti *et al*., 2028)**. Moreover, low pH has been shown to impair growth and survival in Nilem fish **(Sa'adah *et al*., 2023)**, confirming the need for pH regulation. Overall, the combination of appropriate lighting—particularly blue light—and well-maintained water quality is essential for enhancing the intensive aquaculture performance of Seabass juveniles.

Fig. 5. During the experiment, seabass juveniles (*Lates calcarifer*) were infected with *Vibrio vulnificus* (Source: Personal documentation, 2024)

Fig. 6. Clinical symptoms of *Vibrio vulnificus* infection in seabass juveniles (*Lates calcarifer*), adapted from **Zaenuddin (2019)**

CONCLUSION

The results of this study demonstrate that blue light spectrum exposure significantly influenced the growth performance and survival rate of seabass (*Lates calcarifer*) juveniles. Blue light treatment resulted in the highest specific growth rate in both weight and length, and achieved a 100% survival rate, with no mortalities recorded throughout the experimental period. This suggests that blue light provides an optimal environment for physiological and feeding behavior, supported by light intensity within the species' tolerance range. Furthermore, the enhanced feed conversion efficiency observed under this treatment reinforces the role of light manipulation as a key environmental management factor in aquaculture productivity. These findings may be adopted as a basis for developing Standard Operating Procedures (SOP) in seabass hatchery or nursery operations, particularly regarding the selection of artificial light spectrum. Using blue LED lighting in practice could enhance production efficiency and improve juvenile rearing success under closed or semi-intensive systems. However, it is important to acknowledge that the present study was conducted with a relatively small sample size (45 fish), which may limit the statistical power of the findings. The sample size was determined based on system capacity and animal welfare considerations, yet the observed trends were consistent across treatments. Further long-term studies involving larger sample sizes and more comprehensive physiological parameters are recommended to validate these findings and assess their implications for sustainable production performance.

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