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# Effectiveness of LED Light Spectrum Exposure on the Growth and Color Quality of the Rainbowfish *Melanotaenia boesemani*

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**ABSTRACT**

This study aimed to evaluate the growth and color quality of the boesemani rainbowfish exposed to different light spectra. The boesemani rainbowfish, with an average weight of 1.46± 0.23g and length of 4.67± 0.25cm, were reared in an aquarium (33×50×40cm) for 60 days. The fish were fed commercial floating pellets twice a day till satiation. The study involved five treatments with three replications: treatment C (control), W (white LED), R (red LED), G (green LED), and B (blue LED). The results showed that exposure to blue LED light produced the best growth outcomes. The daily growth rate was 0.65± 0.12%, the absolute weight gain was 0.01±0.002g/ head/ day, and feed efficiency was 32.68± 10.59%. Red LED exposure resulted in the best color quality, with visual color performance measured at 51.32± 1.10% for blue, 51.58± 0.97% for orange, and 461±11 chromatophores per fish. Glucose levels ranged from 72.42± 29.60 to 99.13± 5.68mg/ dL. Fish stamina, measured by their ability to swim against the current, ranged from 61.26± 38.74% to 82.33± 17.67%.

## INTRODUCTION

The boesemani rainbowfish, with a commercial name as the rainbowfish, is a highly prized ornamental fish that holds considerable economic importance. The boesemani rainbowfish (*Melanotaenia boesemani*) is an endemic freshwater ornamental fish originating from the island of Papua. The primary attraction of this fish is in its body color, which transitions from blackish blue toward the head to a vibrant blue toward the tail and culminating in a vivid orange tail. The price of the boesemani rainbowfish reaches 8.90$/head, measuring between 6 and 7.5cm in size **(Allen, 1991)**.

The rainbowfish are harvested in their natural habitat to meet customer demand. The rainbowfish is thought to go extinct if exploration proceeds without preserving it. Since 2007, efforts have been made to protect the rainbowfish in their native environment. A number of the rainbowfish expedition teams from BRBIH-BRKP, APSOR-BPSDMKP, and IRD have conducted the rainbowfish conservation activities **(Nur, 2011)**. According to **Umar and Makmur (2006)**, the average catch of the rainbowfish in Sentani Lake (Papua) is around 4.7kg/ day. One species of thw rainbowfish that dominates fishing is the the rainbowfish species *Chilaterina sentaniensis*.

Cultivators have mastered the process of cultivating the rainbowfish. However, the problems that arise from cultivating the fish are the low growth rate, high mortality rate in the larval phase, and poor color quality. For this reason, it is necessary to implement strategies to improve the rainbowfish cultivation system in order to reduce the time to reach selling size, boost the survival rate, and produce fish with high-quality color.

The growth rate of the boesemani rainbowfish is relatively slow. Rearing the boesemani rainbowfish from larvae with a stocking density of 7 fish/L after a rearing period of 20 days results in the growth of 0.9-1.8mm and has a survival rate of 62.33-94.67% **(Kadarini *et al.*, 2013)**. Another study by **Subamia *et al.* (2010)** stated that raising the boesemani rainbowfish measuring 4- 5.6cm requires 3 months and has a daily growth rate (DGR) of 1.16- 1.3%. Based on the research results of **Lukman (2005)**, the rainbowfish during the three-month rearing period reach between 1.2- 3.8cm, and selling size requires six months of rearing.

Accelerating the growth rate of the boesemani rainbowfish can be done by feed engineering or environmental modification. Apart from that, it is necessary to consider the color quality of the boesemani rainbowfish as an appeal. However, the rainbowfish frequently have poor colors. The pigment cells or chromatophores are present in the dermis of fish scales and give fish their color. In general, macroscopic pigmentation in fish can be seen as lines, bands, and spots **(Gustiano, 1992)**.

The spectrum (wavelength), intensity, and photoperiod (duration of exposure) of lighting all have an influence, either directly or indirectly, on fish's physiological response, reproduction, and growth **(Boeuf & Le Bail, 1999)**. When compared to other forms of lighting, employing light-emitting diodes (LED) for cultivation has several advantages. LEDs can reduce costs because they use less power and are more energy-efficient than other types of lighting **(Medkour *et al.*, 2013)**.

Research on the application of LED lights in environmental modification was conducted by **Aras (2015)** using red, blue, green, and white LEDs to observe the growth and color quality of botia fish (*Chrombotia macracanthus Bleeker*). According to a study by **Aras (2015)**, the best result was obtained in green LED with DGR of 2.35± 0.27% and an absolute weight growth (AWG) of 0.030± 0.0003g/ head/ day. Meanwhile, the red LED showed the best effect in visual performance of 75.22± 2.69%. In addition to the spectrum, this research also used an intensity of 550 lux, a photoperiod of 12 hours, and a media with a salinity of 3g L–1. Using an intensity of 550 lux with a 12-hour photoperiod obtained the most significant results in rearing the mackerel with DGR of 5.64 ±0.23% and feed efficiency (FE) of 52.54 ±2.96% **(Nurdin, 2014)**. The use of media with a salinity of 3g L–1 affects the osmoregulation process because the hypertonic state of the fish toward the environment will be reduced (more isotonic). In this situation, less energy is required for regulation, which allows for faster growth and an increase in ammonia and nitrite waste in the water **(Nirmala *et al*., 2005)**.

To the best of our knowledge, studies on the effect of the LED light spectrum on the growth and color quality of the boesemani rainbowfish have not been carried out. The effect of exposure to the LED light spectrum can be used as a breakthrough strategy to boost growth and enhance the color quality of the boesemani rainbowfish in aquaculture systems. Therefore, the current study aimed to evaluate the growth and color quality of the boesemani rainbowfish by exposure to the light spectrum in rearing media.

## MATERIALS AND METHODS

### Time and place

This research was conducted at the Aquaculture Environmental Laboratory, Department of Aquaculture, Faculty of Fisheries and Marine Sciences, Bogor Agricultural University.

### Study design

A completely randomized design (CRD) with 5 treatments and 3 replications was used to conduct the study. The research design was as follows:
1. Treatment **C**: room light (control)
2. Treatment **W**: white LED (465 and 550nm)
3. Treatment **R**: red LED (650nm)
4. Treatment **G**: green LED (525nm)
5. Treatment **B**: blue LED (470nm)

### LED wavelength measurement

The light spectrum of the LEDs was white, red, green, and blue. The light spectrum wavelength was measured by the Ocean Optics USB2000 connected to the Ocean Optics Spectrasuite application. After that, the data were converted using Microsoft Excel 2007 **(Aras, 2015)**. The wavelength table used in the study is presented in Table (1).

**Table 1.** Wavelength of LED light

| Treatment | Wavelength Peak (nm) | | |
|---|---|---|---|
| | LED light | Literature (Aras 2015) | Literature (Effendi 2003) |
| C (Control) | - | - | - |
| W (White LED) | 465 & 550 | 465 & 550 | - |
| R (Red LED) | 650 | 650 | 700 |
| G (Green LED) | 525 | 525 | 520 |
| B (Blue LED) | 470 | 470 | 460 |

## Animal preparation

The boesemani rainbowfish were obtained from the boesemani rainbowfish farmers in the Ciputat. The boesemani rainbowfish had an average weight of 1.46± 0.23g and an average length of 4.67± 0.25cm. The fish were adapted in the containers provided and fed with commercial floating pellets at satiation twice a day at 8.00 AM and 4.00 PM.

## Container preparation and adaptation

Fifteen aquariums measuring 30×50×40cm were arranged on the table as the container. The aquariums were cleaned and filled with 30L of water. The walls of the aquarium were covered with black plastic for all treatments (control, white, red, green, and blue LED). The LED light was connected to a transformer stored on the table, then connected to an automatic timer, which automatically turned on at 6.00 AM and turned off at 6.00 PM. The automatic timer was connected directly to the available electrical supply. The LED lights were installed above the water surface using ropes. The fish were acclimated in water that had a salinity of 3g $L^{-1}$ for 7 days. The fish were fasted one day prior to stocking, and their initial body weight was measured. The stocking density of fish per treatment was 15 fish/aquarium.

## Fish maintenance

Fifteen (30×50×40cm) aquarium containers were used for fish maintenance, and these were placed on the table. The maintenance aquarium layout scheme is displayed in Fig. (1).

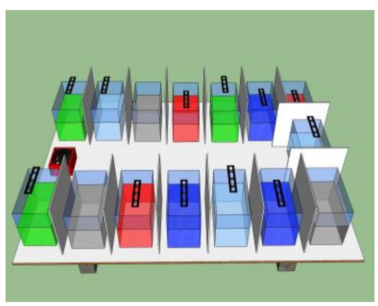


**Fig. 1.** Aquarium layout in experiment

The maintenance medium had a salinity of 3g $L^{-1}$. Fish were fed twice a day at 8.00 AM and 4.00 PM using commercial floating pellets. Fish were reared for 60 days under various LED light spectrum exposures. The LED light was connected to a 12-volt transformer, and the transformer was connected to an automatic timer. The LED lights were automatically turned on at 6.00 AM and turned off at 6.00 PM. The intensity of LED light was 550 lux with a photoperiod of 12 hours. Each LED lamp had a different distance to the water surface to achieve an intensity of 550 lux. Table (2) shows the distance between an LED lamp with an intensity of 550 lux and the water surface.

**Table 2.** Lamp distance and LED light spectrum intensity

| Treatment | Lamp Distance (cm) | Intensity (lux) |
|---|---|---|
| Control | - | 40 |
| White LED | 43 | 550 |
| Red LED | 16 | 550 |
| Green LED | 35 | 550 |
| Blue LED | 13 | 550 |

## Survival rate

The fish survival rate is the percentage of live fish remaining from the total fish reared until the end of treatment. The following formula was used to calculate the fish survival rate **(Zonneveld *et al.*, 1991):**

$$SR\ (\%) = \left(\frac{Nt}{N0}\right) \times 100$$

Where:

SR = survival rate (%)
Nt = number of fish at the end of treatment
No = number of fish at the start of treatment

## Daily growth rate (DGR)

The DGR was determined by weighing the fish at the beginning and end of the treatment and then calculating the average weight. DGR was calculated using the formula **(Zonneveld *et al.*, 1991)**:

$$DGR\ (\%) = \left(\sqrt[t]{\frac{Wt}{W0}} - 1\right) \times 100$$

Where:

Wt = average weight of fish t (g)
Wo = average weight of fish 0 (g)
t = maintenance time

## Absolute weight growth (AWG)

AWG is the subtraction between the final average weight (Wt) and the initial average weight (Wo) of the treatment, then divided by the length of treatment (t). AWG was calculated using the formula **(Zonneveld *et al.*, 1991)**:

$$AWG\ (g/head/day) = \frac{Wt - Wo}{t}$$

where:

Wt = average weight of day t (g)
Wo = average weight on day 0 (g)
t = length of treatment

### Total feed consumption (TFC)

TFC is the quantity of feed consumed during treatment. The following formula was used to determine TFC **(Zonneveld *et al.*, 1991)**:

TFC = the amount of initial feed weighed (g) – residual feed (g)

### Body length growth (BLG)

BLG of fish was measured at the beginning and end of rearing using millimeter blocks. BLG was calculated using the following equation **(Zonneveld *et al.*, 1991)**:

BLG (cm) **=** Pt – Po

Where:
Pt = length of fish at the end of rearing (cm)
Po = length of fish at the start of rearing (cm)

### Feed efficiency (FE)

FE shows how much feed is utilized by fish from the total feed given. FE was calculated using the following formula **(Zonneveld *et al.*, 1991)**:

$$FE\ (\%) = \frac{[(Wt + Wd) - Wo]}{F} \times 100$$

Where:
Wt = fish biomass at the end of rearing (g)
Wd = dead fish biomass during rearing (g)
Wo = fish biomass at the start of rearing (g)
F = amount of feed given (g)

### Glucose

Glucose measurement was conducted by grinding the entire fish's body and then giving a 3.8% Na-Citrate solution with a body: Na Citrate ratio of 1:3 **(Nandiwardhana 2014)**. Fish samples from each treatment were collected in order to perform the glucose measurement. After pounding the fish until it was smooth, a 3.8% Na-Citrate solution– three times its body weight– was added. Subsequently, the body parts were centrifuged at 4032 xg for 15 minutes. The supernatant formed was extracted, separated, and observed using a spectrophotometer with a wavelength of 500nm.

### Stamina test

Stamina tests were performed on gutters installed at a 30° angle and were then filled with running water at a current speed of 0.4m/ s. Then, the test fish were placed in the gutter in the same number as the total fish that remained alive at the end of each treatment's rearing. After 20 seconds, fish that swam against the current and were carried by the current were recorded.

## Visual color performance

Color performance was observed visually at the end of rearing using a 16-pixel DSLR camera. In order to maintain consistent light levels for every picture, the camera was set to operate in manual mode. The fish taken were samples of the fish population from each treatment. After obtaining the image, it was analyzed using the color gradation conversion method according to scale and percentage using the Adobe Photoshop application, which was also used in **Aras (2015)** research. The visual color display method is shown in Fig. (2).

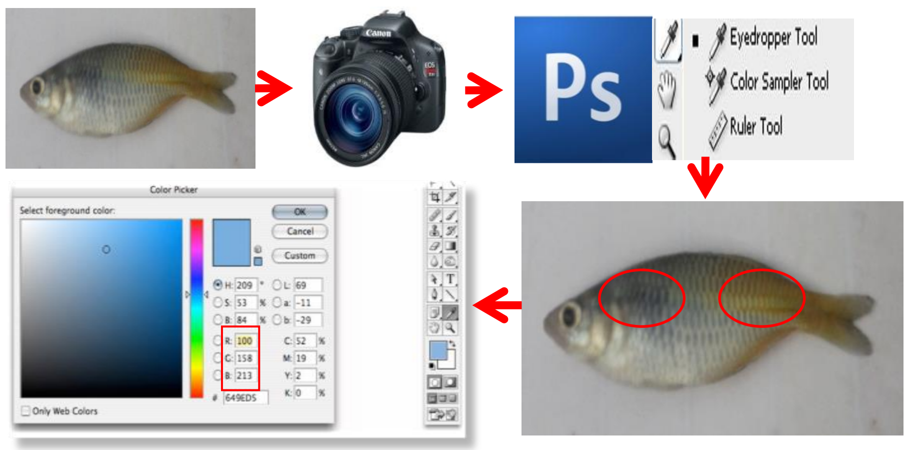



**Fig. 2**. The visual color display method

## Number of chromatophore cells

Chromatophore cell counts in the dermis layer of the fish body were performed at the beginning and end of the study. A histology technique with hematoxylin and eosin staining was used. This approach refers to research by **Aras (2015)**. The body parts observed were cut vertically in the blue and orange parts. The thickness of the section cut was 5µm. After that, a 40×10 magnification microscope was used to examine the preparations.

## Physical chemical quality of water

Measurements of temperature, pH, dissolved oxygen (DO), ammonia, and nitrite parameters were conducted on days 0, 30, and 60. Parameters and tools for measuring water quality parameters are presented in Table (3). Measurements were carried out at the Aquaculture Environmental Laboratory, Department of Aquaculture, Faculty of Fisheries and Marine Science, Bogor Agricultural University.

**Table 3.** Parameters and tools for measuring water quality

| No | Parameters | Tools |
|---|---|---|
| 1 | Temperature | Thermometer |
| 2 | pH | pH meter |
| 3 | DO (mg $L^{-1}$) | DO Meter |
| 4 | Ammonia (mg $L^{-1}$) | Spectrophotometer |
| 5 | Nitrite (mg $L^{-1}$) | Spectrophotometer |

DO: dissolved oxygen

### Data analysis

This study used a completely CRD with 5 treatments and 3 replications. The data were processed using MS Excel 2007 and statistically analyzed with SPSS 22.0, including Analysis of Variance (ANOVA) at a 95% confidence interval. Duncan multiple range test (DMRT) was carried out to determine the effect of the treatment given on all test parameters. Meanwhile, water quality data were analyzed descriptively.

## RESULTS AND DISCUSSION

### Growth and survival performance

The growth performance of the boesemani rainbowfish *(Melanotaenia boesemani)* during 60 days of rearing given exposure to different LED lights is presented in Table (4). The study result showed that the LED light exposure had a significant difference ($P< 0.05$) in the DGR, AWG, TFC, and FE. The blue LED treatment exhibited the highest DGR, measuring 0.65± 0.12%, whereas the white LED treatment showed the lowest DGR, measuring 0.31± 0.22%. The highest AWG was found in the blue LED treatment at 0.01± 0.002g/ head/ day, while the lowest AWG was in the white LED treatment at 0.005± 0.004g/ head/ day. The green LED treatment had the highest amount of TFC at 38.90± 0.70g, while the red LED treatment had the least amount of total feed at 23.86± 0.87g. The best FE was found in the blue LED treatment at 32.68± 10.59%, whereas the green LED treatment had the lowest FE measuring 13.26± 3.85%. Results on survival rate (SR) and body length growth (BLG) were not significantly different ($P>0.05$) after exposure to LED light. The boesemani rainbowfish had a survival rate ranging from 77.78± 3.85% to 86.67± 6.67%. The body length growth of rainbowfish was 0.31± 0.14-0.47±0.11cm. Growth performance and survival rates are presented in Table (4).

The ability of fish to respond to light stimulation (phototaxis) is closely related to the sense of sight or eyes. The cells known as cone and rod cells are cells that react to light stimulation. The cone cells are related to vision in bright conditions, while rod cells are associated with low light **(Hickman *et al.*, 2011)**. The photoreceptors in the fish vision system can absorb peaks of different wavelengths. This condition is supported by the large amount of visual pigment in the retina and the ability to absorb solar energy **(Fitri & Asriyanto, 2009)**.

**Table 4.** Data on growth parameters of the boesemani rainbowfish (*Melanotaenia boesemani*)

| Parameters | Treatments | | | | |
|---|---|---|---|---|---|
| | C | W | R | G | B |
| SR (%) | 86.67±11.54[a] | 86.67±6.67[a] | 77.78±3.85[a] | 84.44±3.85[a] | 84.44±13.88[a] |
| DGR (%) | 0.40±0.11[ab] | 0.31±0.22[a] | 0.41±0.07[ab] | 0.39±0.13[ab] | 0.65±0.12[b] |
| AWG (g/head/day) | 0.007±0.002[ab] | 0.005±0.004[a] | 0.007±0.001[ab] | 0.006±0.002[ab] | 0.01±0.002[b] |
| BLG (cm) | 0.40±0.03[a] | 0.31±0.14[a] | 0.41±0.11[a] | 0.42±0.12[a] | 0.47±0.11[a] |
| TFC (g) | 24.30±0.71[a] | 27.77±2.66[b] | 23.86±0.87[a] | 38.90±0.70[c] | 26.50±2.46[ab] |
| FE (%) | 22.59±8.18[ab] | 15.93±13.05[ab] | 21.96±3.20[ab] | 13.26±3.85[a] | 32.68±10.59[b] |

Note: C: (control) room light; W: white LED; R: red LED; G: green LED; B: Blue LED. SR: survival rate; DGR: daily growth rate; AWG: absolute weight growth; BLG: body length growth; TFC: total feed consumption; FE: feed efficiency. Different superscript letters behind the standard deviation in the same row indicate significantly different results ($P < 0.05$).

The ability of fish to respond to light stimulation (phototaxis) is closely related to the sense of sight or eyes. The cells known as cone and rod cells are cells that react to light stimulation. The cone cells are related to vision in bright conditions, while rod cells are associated with low light **(Hickman *et al.*, 2011)**. The photoreceptors in the fish vision system can absorb peaks of different wavelengths. This condition is supported by the large amount of visual pigment in the retina and the ability to absorb solar energy **(Fitri & Asriyanto, 2009)**.

The cone cells form a mosaic arrangement with four double cone cells encircling a single cone cell. With these double-cone cells, fish are able to distinguish colors. The diameter of the lens and the density of cone cells in the retina are the two factors that determine a fish's visual acuity. The image of an object passing through the eye lens to the retina speeds up with an increase in eye lens diameter because the value of the smallest differentiating angle becomes smaller **(Fitri & Asriyanto, 2009)**.

Survival rate is a percentage comparison of the number of fish remaining alive at the end of rearing to the number of fish at the beginning of rearing. The survival rate of boesemani rainbowfish during rearing was not significantly different ($P>0.05$) across treatments. The boesemani rainbowfish had a survival rate ranging from 77.78± 3.85% to 86.67± 6.67%. For boesemani rainbowfish, variations in light spectrum treatments did not affect the survival rate. According to **Kadarini and Prihandani (2011)**, the survival rate of fish is considered good if the presentation of live fish reaches 80-90%.

The highest DGR was in the blue LED treatment at 0.65± 0.12%, which was significantly different ($P<0.05$) from other treatments. The highest AWG was also in the blue LED treatment at 0.01± 0.002g/ head/ day ($P<0.05$). The growth rate of fish depends on their capacity to digest and utilize the feed provided as optimally as possible **(Kadarini & Prihandani, 2011)**. When exposed to blue LED light, the result is directly proportional to the FE level as it had the highest value. According to **Elsbaay (2013)**, blue light with a 24-hour photoperiod yielded the best DGR and AWG in tilapia (4.05%

and 17.3%, respectively) with a growth efficiency of 0.29. **Ruchin (2005)** stated that exposure to blue light produced the best growth for guppy fish. Other research by **Shin *et al.* (2011)** said that lower spectrum exposure is associated with a reduced stress response compared to other spectrum exposures. In addition, exposure to the blue spectrum improves immune function and weight gain in the yellowtail damselfish. Fish respond differently to variations in the light spectrum in terms of growth, physiology, behavior, and reproduction **(Karakatsouli *et al.*, 2007)**. According to **Nurdin (2014)**, rearing the tinfoil barb at a light intensity of 550 lux results in a relatively faster growth in fish weight and length. It is suspected that fish grow faster when exposed to a light intensity of 550 lux because it is easier for young fish to see and consume food.

The highest amount of TFC was in the green LED treatment at 38.90±0.70g, indicating a significant difference ($P < 0.05$) from other treatments. The green spectrum increased the feed consumption because the green spectrum emits brighter light, thus clarifying the appearance of the feed in the water. With the same intensity of 550 lux, the green LED distance was higher than red and blue (monochromatic) LEDs. This is in accordance with the finding of **Boeuf and Le Bail (1999)**, who reported that the color of light can influence growth and can increase the rate of feed consumption. In general, higher light intensity often allows for more optimal growth, such as light intensity of 600-1300 lux that caused an optimal growth of the seabream fish.

The indicator for feed utilization is the percentage of FE. FE measures the ratio of producing fish biomass to the amount of feed given during rearing. The blue LED treatment had the highest FE at 32.68±10.59%, showing significantly different results ($P < 0.05$). The nutritional absorption of feed given to the rainbowfish was optimal in the blue LED treatment. **Elsbaay (2013)** reported that tilapia exposed to the blue color spectrum had the best feed conversion of 1.04±0.01 with a FE of 96.15%. The rearing of *Sparus aurata* exhibited the highest FE in the blue spectrum exposure at 86.2% **(Karakatsuoli *et al.*, 2007)**.

## Physiological response

### Glucose level

The body glucose level of the boesemani rainbowfish during 60 days of rearing is presented in Fig. (3). Fish with white LED exposure had the highest body glucose levels (99.60±5.68mg $dL^{-1}$), while the red LED-exposed fish had the lowest body glucose levels (62.03±11.87mg $dL^{-1}$). Following exposure to the LED light spectrum, the glucose levels rose.

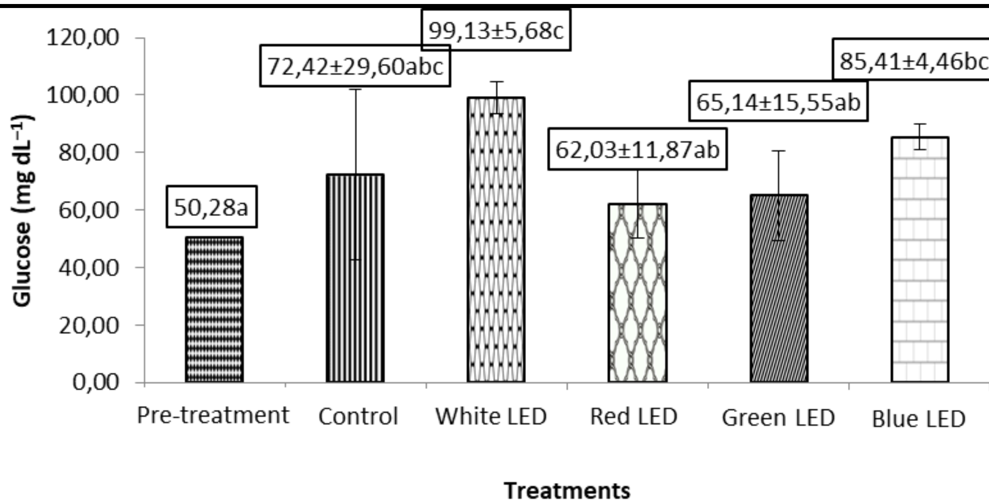



**Fig. 3.** Body glucose levels of boesemani rainbowfish *(Melanotaenia boesemani)* in fish before treatment (H0), control (C), white LED (W), red LED (R), green LED (G), and blue LED (B)

Different superscript letters indicate significantly different results (*P*< 0.05).

The highest body glucose levels were found in the white LED treatment at 99.60± 5.68mg dL$^{-1}$, showing significantly different (*P*< 0.05) results from other treatments. The increase in blood glucose levels compared to the condition before treatment was thought to be caused by stress brought on by the treatment given. According to **Mazeaud and Mazeaud (1981)** and **Hastuti *et al.* (2003)**, stress determines the presence of glucose in fish bodies. These results correlated with the DGR and AWG of the white LED treatment, which had the lowest values (0.31± 0.22% and 0.005± 0.004g/ head/ day, respectively) compared to other treatments (*P*< 0.05). The amount of TFC had no direct effect on raising glucose levels (Table 4 & Fig. 1). Since stress hormones can affect blood glucose levels, hyperglycemia is an indicator of early stress. The elevated glucose level indicates the mounting level of stress due to the treatment given. Death will occur after a fast rise in glucose that remains at high levels under severe stress **(Brown, 1993 in Hastuti *et al.*, 2003)**.

## Stamina

Fig. (4) presents the stamina of the boesemani rainbowfish during 60 days of rearing. The strongest stamina was in the red LED treatment at 82.33± 16.18%, while the weakest stamina was in the room light treatment at 61.26± 35.84%.

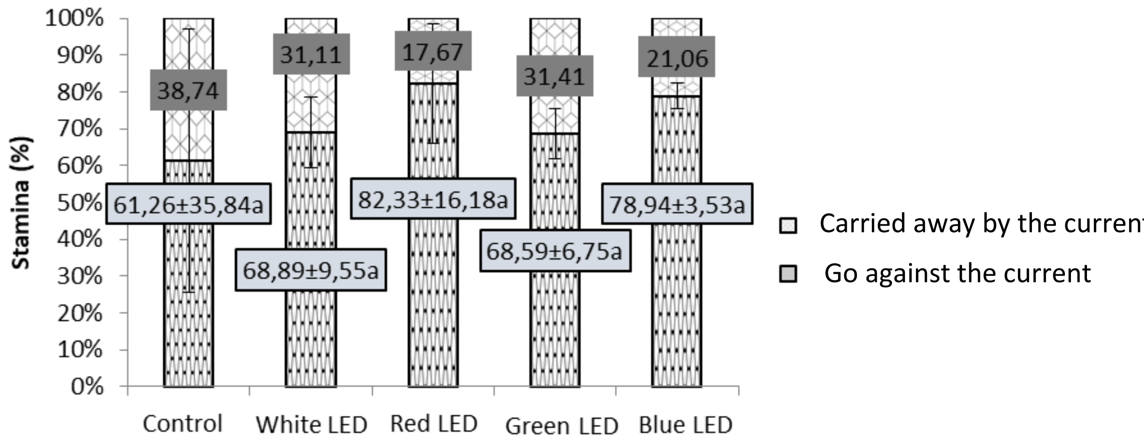



**Fig. 4.** Stamina of boesemani rainbowfish *(Melanotaenia boesemani)* in the control (C), white LED (W), red LED (R), green LED (G), and blue LED (B) treatments
Different superscript letters indicate significantly different results (*P*< 0.05).

The findings demonstrated that the stamina of the boesemani rainbowfish was influenced by the light spectrum. It is observed that the fish's stamina increases with the higher wavelength of light provided. When related to glucose levels, the red spectrum had a lower value than other treatments. The red LED-exposed fish had greater stamina because the fish's glucose state was not under stress. Additionally, there was an interaction between spectrum and light intensity. The light intensity employed in the light spectrum treatment was 550 lux, while the light intensity in the control treatment only reached 40 lux. Fish's immune system strengthens with longer spectrum wavelengths and greater light intensity. However, this result was in contrast to the study by **Boeuf and Le Bail (1999)**, who stated that high light intensity can be stressful and even fatal. The research results of **Setiadi *et al.* (2002)** showed that the optimal intensity is 500 lux, and as the light intensity rises, so does the mortality of Red-spotted grouper *Epinephelus akaara* larvae.

## Color quality
### Chromatophore cells

The number of chromatophore cells in boesemani rainbowfish during their 60-day rearing period is presented in Figs. (5, 6). The red LED treatment had the maximum number of chromatophore cells at 461± 11 cells, while the room light treatment (control) had the lowest number of chromatophore cells at 135± 17 cells.

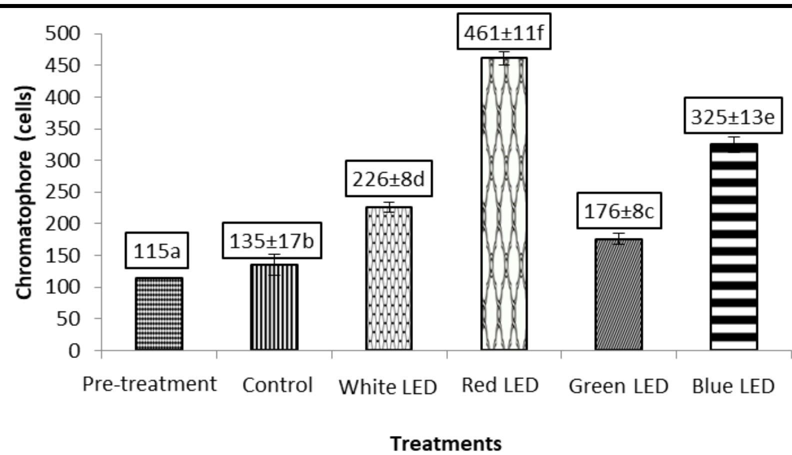
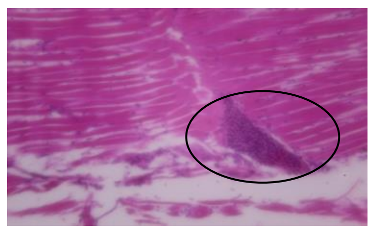


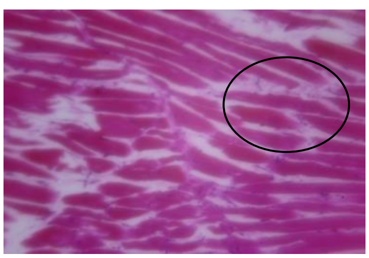

**Fig. 5.** Number of chromatophore cells in the boesemani rainbowfish *(Melanotaenia boesemani)* before treatment (H0), control, white LED (W), red LED (R), green LED (G), and blue LED (B)

Different superscript letters indicate significant differences ($P < 0.05$).

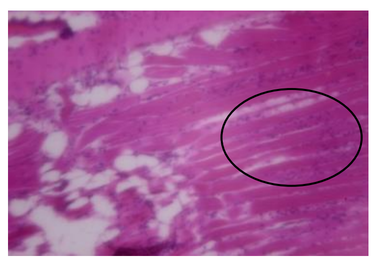
Before treatment (H0)



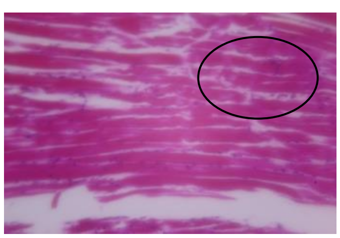
Control



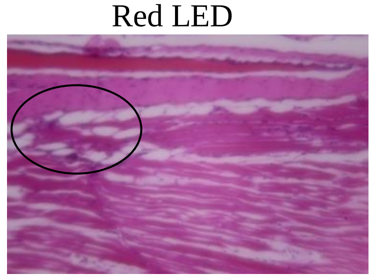
White LED



Red LED



Green LED



Blue LED

**Microscope magnification scale 40×10**

**Fig. 6.** Boesemiani rainbowfish chromatophore cells observed under a microscope with a magnification of 40×10 before treatment (H0), control, white LED (W), red LED (R), green LED (G), and blue LED (B)

Note: The circle shows the presence of boesemani rainbowfish chromatophore cells.

The highest visual color performance of the blue part was observed in the red LED treatment at 51.32±1.10%, while the lowest was in the control treatment at 38.45±1.08%. Additionally, the best visual color performance of the red part was also documented in the red LED treatment at 51.58± 0.97%, while the lowest was in the control treatment at 39.63± 1.2%. The blue and red visual color performance improved after being exposed to the LED spectrum. This best result was obtained in the red LED spectrum and is directly proportional to the results of chromatophore cells with 461±11 cells. Thus, the best color quality was produced in the red LED spectrum treatment. The maintenance media conditions tended to be darker compared to other treatments. **Evans (1993)** asserted that the likelihood of light penetrating water increases with decreasing light wavelength. In contrast, there is less chance of light passing through water with greater light wavelength. These results are in accordance with research by **Tume *et al.* (2009)**, who stated that employing a dark background can enhance the amount of pigment in *P. monodon*.

The LED spectrum with short wavelengths has more photon energy than the LED spectrum with long wavelengths. The green LED spectrum has a wavelength of 525nm. It is thought that exposure to the green LED makes the appearance of food in the water more evident and increases fish appetite. These outcomes were positively correlated. The amount of feed consumption in the green LED treatment had the highest value compared to other treatments ($P< 0.05$).

Nevertheless, the high feed consumption in the green LED treatment was not accompanied by high FE. The highest FE was found in the blue LED treatment because it is suggested that the blue LED produced more photon energy. Thus, the fish were better equipped with energy to digest the feed optimally. Aside from that, the glucose level in the blue LED was relatively lower than in the white LED treatment. High glucose levels indicate stressed fish. However, because glucose level is a secondary stress response, elevated glucose levels cannot be used as an absolute parameter to determine stress levels **(Hastuti *et al.*, 2003)**.

### Visual color performance

The visual color performance of the boesemani rainbowfish is presented in Table (5). The blue part’s visual color performance was the highest (51.32±1.10%) in the red LED treatment, while the lowest (38.45±1.08%) was in the control treatment. The visual color performance of the red part was also the greatest in the red LED treatment (51.58±0.97%) and the lowest in the control treatment (39.63±1.12%). Visual color performance in blue and red parts increased after being exposed to the LED spectrum. In Fig. (7), pictures of the boesemani rainbowfish are presented visually.

The boesemani rainbowfish can be seen visually after being exposed to the LED light spectrum, as shown in Fig. (7).

**Table 5.** Visual color performance of the boesemani rainbowfish (*Melanotaenia boesemani*)

| Treatments | Boesemani Rainbowfish Color Quality (%) | |
|---|---|---|
| | Blue Color | Orange Color |
| H0 | 37.01±0.00$^{a}$ | 38.36±0.00$^{a}$ |
| C | 38.45±1.08$^{ab}$ | 39.63±1.12$^{ab}$ |
| W | 39.80±1.74$^{b}$ | 47.04±3.37$^{c}$ |
| R | 51.32±1.10$^{d}$ | 51.58±0.97$^{d}$ |
| G | 40.59±0.94$^{b}$ | 41.77±1.01$^{b}$ |
| B | 44.14±1.77$^{c}$ | 44.73±0.91$^{c}$ |

Note: H0: before treatment; C: (control) room light; W: white LED; R: red LED; G: green LED; B: blue LED. Different superscript letters behind the standard deviation in the same column indicate significant differences ($P$<0.05).

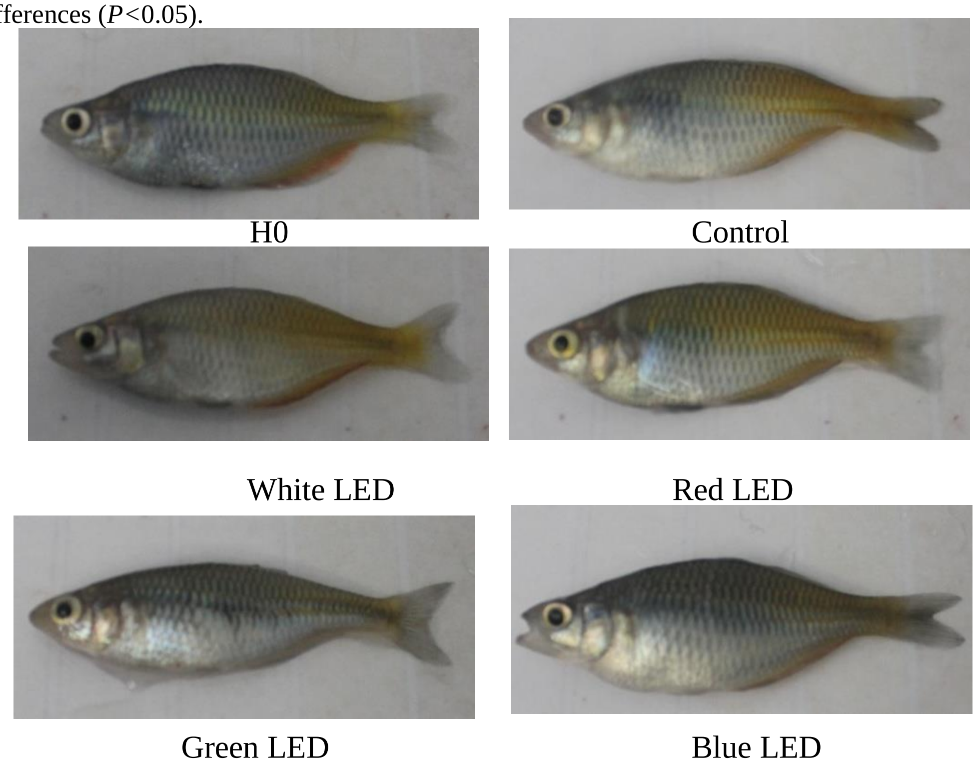



Image scale 1: 2.5

**Fig. 7.** Visual observation of the rainbowfish *(Melanotaenia boesemani)* color quality before treatment (H0), control (C), white LED (W), red LED (R), green LED (G), and blue LED (B)

Because the fish were able to make greater use of the feed when exposed to the blue LED than when exposed to other treatments, high FE in the blue LED treatment led to the best DGR, AWG, and body length growth. However, the blue LED spectrum treatment did not produce the best stamina and color quality. The best stamina and color quality were found in the red LED treatment. Red LEDs produce little photon energy and low penetration into water, causing the media exposed to red LEDs to be darker and contain lower energy. In dark conditions, fish are more silent and store much energy. Therefore, when evaluated for stamina, the fish in the red LED treatment showed more stamina than the other treatments. In addition, fish under red LED treatment had the lowest glucose level, indicating that they were not under stress. The dermis of the scales contains the greatest concentration of pigment cells, or chromatophores, under dark conditions. It will generate more vibrant colors in these situations **(Evans, 1993)**. This outcome also occurs when rearing *P. monodon* in a dark container, which intensifies the color pigment **(Tume *et al.*, 2009)**.

**Physical chemical water parameters**

Table (6) displays the physical and chemical water quality parameters carried out when rearing the boesemani rainbowfish for 60 days. The temperature was 25.8-27.6°C. DO during rearing was 4.6-5.9mg $L^{-1}$. The boesemani rainbowfish was reared in an environment with pH values between 7.11 and 7.57. Nitrite levels varied between 0.017 and 0.086mg $L^{-1}$, and the range of ammonia was around 0.002-0.0011mg $L^{-1}$.

**Table 6.** Physical and chemical water parameters of the boesemani rainbowfish *(Melanotaenia boesemani)* during rearing

| Parameter | Treatments | | | | | Optimal Range |
|---|---|---|---|---|---|---|
| | C | W | R | G | B | |
| Temperature (°C) | 25.9-27.6 | 26-27.5 | 26.1-27.5 | 25.9-27.4 | 25.8-27.4 | 25-27 (Subamia *et al.* 2010) |
| DO (mg/L) | 5.4-5.8 | 5.3-5.7 | 4.6-5.8 | 4.9-5.8 | 5.2-5.9 | 4.05-5.25 (Subamia *et al.* 2010) |
| pH | 7.11-7.25 | 7.23-7.55 | 7.23-7.46 | 7.33-7.57 | 7.31-7.43 | 6.5-9.0 (Boyd 1982) |
| Nitrite (mg/L) | 0.017-0.056 | 0.028-0.056 | 0.035-0.056 | 0.018-0.086 | 0.030-0.084 | <0.5 (Boyd 1982) |
| Ammonia (mg/L) | 0.007-0.008 | 0.002-0.009 | 0.003-0.009 | 0.003-0.011 | 0.003-0.011 | <0.52 (Boyd 1982) |

Note: C: (control) room light; W: white LED; R: red LED; G: green LED; B: blue LED.

The physical and chemical parameters of water are external factors that can influence the success of cultivation. Along with feed and genetic factors, water quality can indirectly affect growth and survival. The water quality parameters measured in this treatment were temperature, dissolved oxygen, pH, nitrite, and ammonia. Table (6) presents the range of results from water quality measurements carried out throughout the 60-day rearing of the boesemani rainbowfish. Temperatures ranged from 25.8 to27.6°C. According to **Subamia *et al.* (2010)**, the rearing temperature for the boesemani rainbowfish is between 25-27°C, which is still adequate for the life of the boesemani rainbowfish. In this study, DO levels ranged from 4.6 to 5.9mg $L^{-1}$ (Table 6). The boesemani rainbowfish raised in DO of 4.05–5.25mg $L^{-1}$ is appropriate to sustain a fish's life **(Subamia *et al*., 2010)**. The pH during rearing the boesemani rainbowfish in this study ranges from 7.11 to 7.57. According to **Boyd (1982)**, 6.5-9.0 is a good pH range for water. Nitrite levels during maintenance varied between 0.017 and 0.086mg $L^{-1}$. A good nitrite range, according to **Boyd (1982)**, should be less than 0.5mg $L^{-1}$. Based on these findings, nitrite levels in this study were still very favorable for the boesemani rainbowfish survival. The water ammonia level ranged from 0.002 to 0.0011mg $L^{-1}$. **Boyd (1982)** stated that an acceptable range for ammonia in water is less than the lethal limit of 0.52mg $L^{-1}$.

## CONCLUSION

The blue LED light spectrum produced the best weight growth performance based on DGR, AWG, and FE. Meanwhile, the red LED light spectrum yielded the best color quality based on visual color performance and the number of chromatophore cells.

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