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Optimum light wavelength and light intensity for rearing juvenile African Catfish (*Clarias gariepinus*)

Muhammad Firdaus Sallehudin[1], Nor Amira Yusoff[1], Nai Han Tan[1], Shahbudin Saad[2] and Yukinori Mukai[2]*

1) Department of Biotechnology, Kulliyyah of Science, International Islamic University Malaysia, Jalan Sultan Ahmad Shah, Bandar Indera Mahkota, 25200 Kuantan, Pahang, Malaysia.
2) Department of Marine Science, Kulliyyah of Science, International Islamic University Malaysia, Jalan Sultan Ahmad Shah, Bandar Indera Mahkota, 25200 Kuantan, Pahang, Malaysia.

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Abstract: The present study examines the optimum light wavelength and intensity for rearing African catfish (*Clarias gariepinus*) juveniles. For this purpose, African catfish juveniles (average total length: 26.0 ± 5.0 mm) were reared (20 fish/30 L) under five light colours (white, blue, green, yellow, and red) with three light intensities (1.40, 0.014, and 0.0014 µmoles/m²/s) in triplicate for 14 days. The survival rates and specific growth rates (SGRs) were then calculated. The results of the present study showed that the survival rates of African catfish juveniles were high under all light conditions with no significant differences among light wavelengths or light intensities ($P < 0.05$). These findings indicate that the survival rates of African catfish juveniles were unaffected either by light wavelengths or by light intensities. However, there were significant differences among light wavelengths for the SGRs, with yellow light resulting in the highest SGR. As for the effect of light intensities on fish growth rates, the results were insignificant. Thus, yellow light is recommended for rearing African catfish juveniles.

Keywords: African catfish, *Clarias gariepinus*, survival rate, growth rate, light intensities, light wavelengths

Introduction

The African catfish, *Clarias gariepinus*, is one of the most important fish species in the aquaculture industry, especially in developing countries such as Mali, Ghana, Nigeria, and South Africa (De Graff and Janssen, 1996). This is because the African catfish have the ability to survive under high stocking density, resist diseases, and withstand poor water quality (Adamek *et al*., 2011). Moreover, they have fast growth rates and good quality meat (Adewolu *et al*., 2008). However, this species shows high cannibalism during the larval and juvenile stages, which has been reported to lead to mortality rates of 70 – 80% in larvae and 40 - 50% in juveniles (Appelbaum and Kamler, 2000). This cannibalistic behaviour could reduce its survival and growth rates (Angela and Nneji, 2013).

One factor that may influence fish survival and growth is light condition (Boeuf and Le Bail, 1999). Catfish species such as African and sutchi catfish are sensitive to light condition (Mukai, 2010; Mukai and Lim, 2011; Mukai *et al*., 2013a; Mukai *et al*., 2013b), and thus rearing them under optimum light conditions could increase their survival and growth rates. Previous studies have found that rearing sutchi catfish under low light intensity can increase their survival rates (Mukai, 2010). Another study found that the growth rates of Chinese longsnout catfish increase when reared under a light intensity of 312 lx (Han *et al*., 2005).

Most previous studies of African catfish have focused on the effect of different light intensities under white light conditions. For instance, the survival and growth rates of the larvae and juveniles of African catfish reared under dark conditions have been found to be higher than those reared under light conditions (Britz and Pienaar, 1992; Appelbaum and Kamler, 2000; Adewolu *et al.,* 2008; Mukai *et al*., 2013a; Mukai and Lim, 2011). Further, Lee *et al*. (2014) stated that African catfish have a colour vision that enables them to discriminate colour and improve their capability of capturing their prey or feeding more efficiently. However, the effects of different light wavelengths on catfish survival and growth rates are still unclear.

Recent studies indicate that a specific light wavelength can increase the survival and growth of certain fish species (Ullmann *et al*., 2011). For example, the survival rates of the haddock larvae are higher when reared under blue and green light

(✉) mukai9166@gmail.com

(Downing, 2002), whereas the survival rates of the Atlantic cod and the turbot larvae are reduced under green light (Sierra-Flores *et al*., 2016). In another study, the growth rates of the rainbow trout were found to be higher under a red light, while green light is preferable for the growth of the silver carp larvae (Radenko and Alimov, 1991; Ruchin, 2004).

Thus, the objectives of the present study are to determine the optimum light wavelength and intensity for the African catfish juveniles in order to increase the survival and growth rates of this fish species and thus increase their production.

Materials and Methods

Juvenile specimens

Experiments were conducted in the aquaculture laboratory of the Kulliyyah of Science, International Islamic University Malaysia (IIUM). Juvenile African catfish, obtained from the Perlok Aquaculture Extension Centre, Jerantut, Pahang, were reared in 40 L plastic aquaria with sufficient aeration and a water temperature of 26.0 - 28.0°C. Juveniles were fed twice daily with a commercial pelleted diet (Cargill Sdn. Bhd., Melaka), and were acclimatised to laboratory conditions until the day of the experiment (average total length ± SD: 26.0 ± 5.0 mm).

Illuminating method and experimental design

The experiments were conducted in dark shelves. Light emitting diodes (LEDs) (10 W high power LEDs, Wayjun Technology Co., Ltd, Shenzhen) were used as the light source, while light intensity was adjusted by using a dimmer (Songyuan Electronics Technology Co., Guangdong Province) and neutral-density filters (ND×8, HOYA, Tokyo). Light intensity was measured by using a spectrometer (USB 4000, Ocean Optics, Inc., Florida). The experiments were conducted under white (broad spectrum with double peaks at 452 and 557 nm), blue (peak, 458 nm), green (528 nm), yellow (593 nm), and red (636 nm) light (Fig. 1), with three light intensities which were 1.40, 0.014, and 0.0014 µmoles/m²/s for 14 days.

For each light condition, 20 juveniles were placed into 40 L plastic aquaria with 30 L of water. The experiments were carried out in triplicate. The total length and body weight of the juveniles were measured and recorded prior to the rearing experiments. The illumination duration for the experiment was set to 12 hours on and 12 hours off. The juveniles were fed with 0.5 g of pellets (crude protein: 45%, crude fat: 8%, crude fibre: 4%, moisture: 11%) (Cargill Sdn Bhd., Melaka) twice per day, which was increased to 0.6 g from day seven of the experiment. To maintain water quality, the aquaria were bottom-cleaned every day to remove fish waste and uneaten food. Thirty percent of the water volume in all aquaria was changed daily. The aquaria were exposed to light for less than 10 minutes to change the water. Water temperature (26.0-28.0°C), dissolved oxygen (7.0 - 8.0 ppm), and water pH (8.0 - 9.0) were monitored daily.

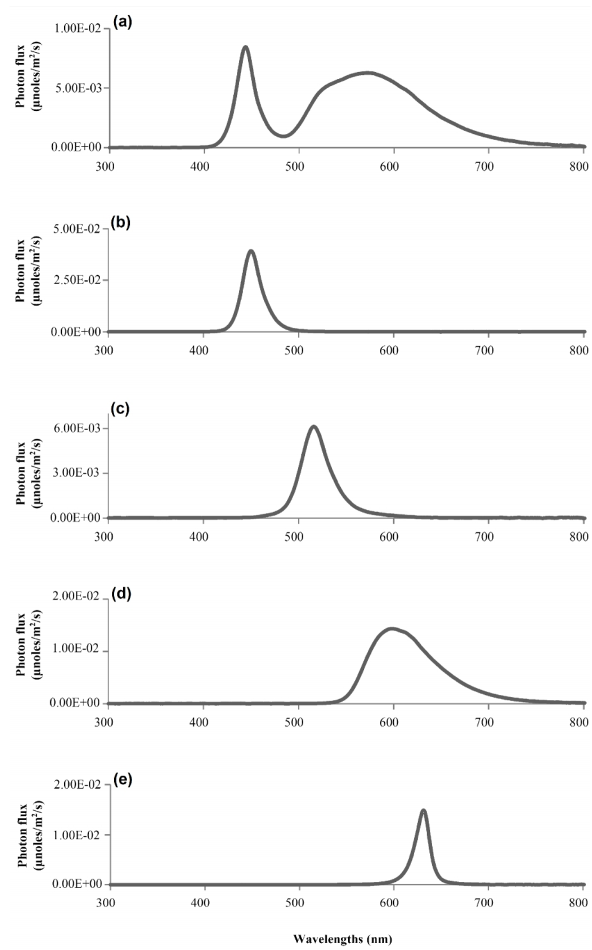

Fig. 1: Spectra for different colour light measured by spectrometer. (a) white light with double peaks at 452 and 557 nm, (b) blue light with peak at 458 nm, (c) green light with peak at 528 nm, (d) yellow light with peak at 593 nm, and (e) red light with peak at 636 nm.

Fish survival and growth rates

At the end of the experiment, the juveniles were anesthetised with Transmore (Nika Trading. Co, Selangor) to determine the survival number and their body weight. Fish survival rates, specific growth rates for total length (SGR_{TL}) and specific growth rates for body weight (SGR_{BW}) were then calculated by following these formulas:

$S = 100 \times (F_f/F_i)$
where:
S = survival rate (%)
F_f = final number of fish (g)
F_i = initial number of fish (g)

$SGR_{TL} = 100 \times (\ln TL_f - \ln TL_i)/D$
where:
SGR_{TL} = specific growth rate for total length (%/day)
TL_f = final mean total length (mm)
TL_i = initial mean total length (mm)
D = rearing time (day)

$SGR_{BW} = 100 \times (\ln BW_f - \ln BW_i)/D$
where:
SGR_{BW} = specific growth rate for body weight (%/day)
BW_f = final mean body weight (g)
BW_i = initial mean body weight (g)
D = rearing time (day)

Statistical analysis

Before analysis, percentage data were transformed by arcsine transformation (Sokal and Rohlf, 1969). Then the data were analysed by using a two-way analysis of variance (ANOVA) with light spectrum and light intensity as the factors. A multiple comparison test was carried out by using Tukey's post-hoc test when *P* values were significant ($P < 0.05$).

Results

Survival rates

The survival rates of African catfish juveniles under different light wavelengths and light intensities are shown in Figure 2. This figure shows that the survival rates of African catfish juveniles for all light conditions ranged from 93.3% to 100.0%. Based on the analysis of the two-way ANOVA, there were no significant differences among the light wavelengths and light intensities.

Specific growth rates for total length (SGR_{TL})

The results of SGR_{TL} for the African catfish juveniles under the different light wavelengths and intensities are shown in Figure 3. This figure shows that the SGR_{TL} values of African catfish juveniles for all light conditions ranged from 2.89% to 4.22%. Based on the results of the two-way ANOVA analysis in Table 1, there was no interaction between light wavelengths and light intensity on the SGR_{TL} of the juveniles. Light wavelength had a significant effect on juveniles' SGR_{TL}. For the effect of light intensities on SGR_{TL}, no significant differences were observed.

Tukey's post-hoc analysis of light wavelengths showed that the SGR_{TL} values under white, green and yellow light were significantly higher ($P < 0.05$) than those under red light. Moreover, the SGR_{TL} value under yellow light was slightly higher than those under white and green light.

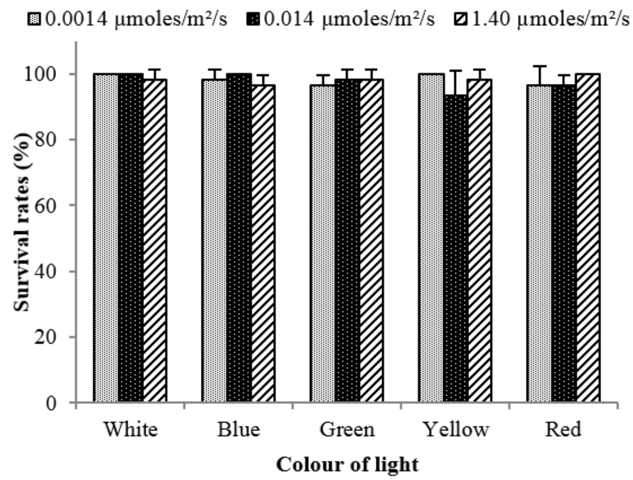

Fig. 2: Survival rates (%) of African catfish *Clarias gariepinus* juvenile under different light wavelengths and light intensities. Data presented as means ± SD (n = 3).

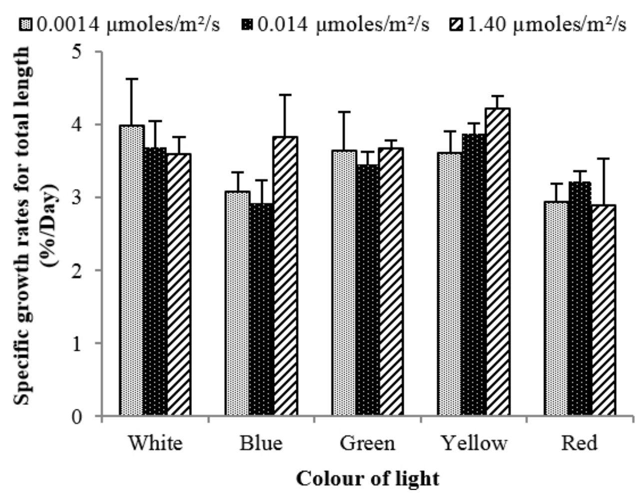

Fig. 3: Specific growth rates of total length (SGR_{TL}) of African catfish *Clarias gariepinus* juvenile under different light wavelengths and light intensities. Data presented as means ± SD (n = 3).

Tab. 1: Results of two-way ANOVA and Tukey's test of specific growth rates for total length (SGR_{TL}) of African catfish *Clarias gariepinus* juveniles under different light wavelengths and light intensities.

Variable	DF	MS	F	Significance
LW	4	2.919	8.584	0.000*
LI	2	0.434	1.276	0.294^{NS}
LW × LI	8	0.651	1.913	0.950^{NS}
Light wavelength	**Mean ± SD**			
White	3.75 ± 0.43^{ab}			
Blue	3.28 ± 0.54^{bc}			
Green	3.59 ± 0.30^{ab}			
Yellow	3.90 ± 0.32^{a}			
Red	3.01 ± 0.38^{c}			
Light intensity (µmoles/m²/s)	**Mean ± SD**			
0.0014	3.45 ± 0.53			
0.014	3.43 ± 0.40			
0.14	3.64 ± 0.57			

LW = Light wavelength; LI = Light intensity; LW×LI = interaction of light wavelength and light intensity. Mean values with no superscript in common differ significantly ($P < 0.05$). If the effects were significant, ANOVA was followed by the Tukey test. * = $P < 0.05$; NS = not significant.

Specific growth rates for body weight (SGR_{BW})

Figure 4 shows the SGR_{BW} of African catfish juveniles under different light wavelengths and light intensities. This figure shows that the SGR_{BW} values of African catfish juveniles for all light conditions were ranged from 8.93% to 12.58%. The two-way ANOVA analysis (Tab. 2) revealed significant differences among the different light wavelengths. However, for light intensities, no significant differences were observed.

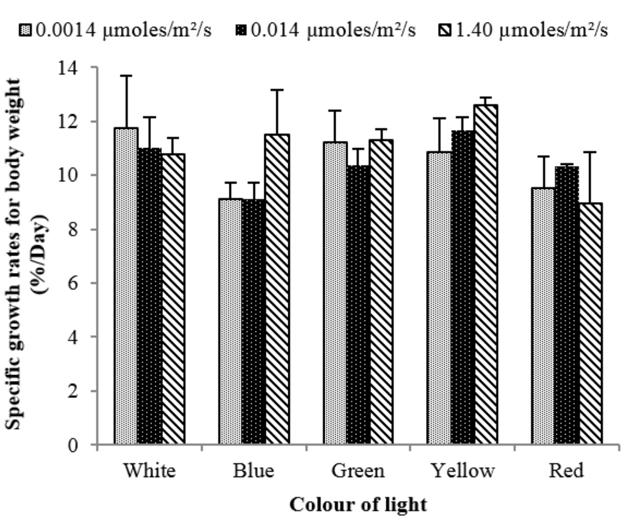

Fig. 4: Specific growth rates of body weight (SGR_{BW}) of African catfish *Clarias gariepinus* juvenile under different light wavelengths and light intensities. Data are means ± SD (n = 3).

Based on Tukey's post-hoc analysis of light wavelengths (Tab. 2), the SGR_{BW} value under yellow light was significantly higher ($P < 0.05$) than those under blue and red light. The SGR_{BW} value under white light was also significantly higher ($P < 0.05$) than that under red light but slightly lower than that under yellow light.

Tab. 2: Results of two-way ANOVA and Tukey's test of specific growth rates for body weight (SGR_{BW}) of African catfish *Clarias gariepinus* juveniles under different light wavelengths and light intensities.

Variable	DF	MS	F	Significance
LW	4.00	6.25	5.92	0.001*
LI	2.00	1.05	0.99	0.383^{NS}
LW × LI	8.00	2.12	2.02	0.079^{NS}
Light wavelength	**Mean ± SD**			
White	11.17 ± 1.24^{ab}			
Blue	9.90 ± 1.52^{bc}			
Green	10.96 ± 0.82^{abc}			
Yellow	11.70 ± 1.03^{a}			
Red	9.60 ± 1.28^{c}			
Light intensity (µmoles/m²/s)	**Mean ± SD**			
0.0014	10.50 ± 1.51			
0.014	10.50 ± 1.05			
1.40	11.01 ± 1.59			

LW = Light wavelength; LI = Light intensity; LW×LI = interaction of light wavelength and light intensity. Mean values with no superscript in common differ significantly ($P < 0.05$). If the effects were significant, ANOVA was followed by the Tukey test. * = $P < 0.05$; NS = not significant.

Discussion

Light condition is one environmental factor that can affect fish survival rates (Boeuf and Le Bail, 1999; Mukai, 2010). Mukai and Lim (2011) showed that the survival rates of African catfish larvae reduce under high light intensities, as the larvae show high cannibalistic behaviour, and similar results have been observed for sutchi catfish (Mukai, 2010). However, the results of the present study did not find a relationship between light conditions and fish survival rates. The differences between current and previous studies of the effect of light conditions on fish survival rates (Mukai, 2010; Mukai and Lim, 2011) could thus be due to the difference in fish stages used in the experiments.

Many studies have revealed that most fish require a minimal threshold of light intensity to be able to develop and grow normally (Boeuf and Le Bail, 1999; Han *et al.*, 2005). Moreover, high light intensity might be stressful for or even lethal to fish (Boeuf and Le

Bail, 1999). In the study conducted by Yusoff *et al*. (2016), the juveniles of sutchi catfish showed the highest growth rates when reared at a light intensity of 1.40 µmoles/m²/s. However, in the present study, light intensity showed no significant difference for fish growth rates. Thus, the results of the present study showed that the growth rates of the African catfish juveniles were not affected by light intensity.

Light wavelengths were shown to have a significant influence on the growth rates of African catfish juveniles in the present study, which were found to be significantly higher under yellow light. The beneficial effect of yellow light on fish growth rates has also been reported in the rainbow trout (Heydarnejad *et al*., 2013). The body weight and total length of the rainbow trout reared under yellow light are greater compared with under other coloured light (white, red and blue light) (Heydarnejad *et al*., 2013). However, for the crucian carp (Ruchin, 2004) and the pikeperch (Luchiari *et al*., 2009), their SGRs are the highest when reared under green light compared with under white, blue, yellow, and red light. These findings indicate that the effect of light wavelength on fish differs between species, which inhabit different water bodies that have specific light environments (Ruchin, 2004). Further, the visual sensitivity of the fish also differs between species (Kawamura *et al.,* 2015; Ullmann *et al*., 2011).

In the present study, African catfish juveniles showed the highest growth rates when reared under yellow light. The effect of light wavelength on fish growth rates could therefore also be related to the colour preferences of fish (Kawamura *et al.,* 2015). The African catfish is a freshwater fish species that dwells in calm lakes, rivers, floodplains, and swamp areas that flood on a seasonal basis (De Graff andJanssen, 1996). The species starts spawning with the onset of the rainy season, which lasts around two to three months (Van Der Hurk *et al*., 2013). During the rainy season, the amount of suspended fine particulate matter such as clay particles increases in the water body. These fine particles are derived from soil erosion and they turn the water yellowish in colour (Kirk, 1985). Additionally, the presence of yellow substances derived from the breakdown of chlorophyll and humic acid in freshwater makes the absorption of light shift towards long light wavelengths (550-560 nm or longer) (Bone *et al*., 1995). Therefore, yellow light is favourable for rearing African catfish juveniles because this light wavelength is similar to the light environment in their natural habitat.

Rearing fish under the optimum light conditions can improve feed ingestion rates (Mukai *et al*., 2012; Volpato *et al*., 2013), thus increasing their growth rates (Yoseda *et al*., 2008). Previous studies of the African catfish have shown better feed ingestion and growth when reared under dark rather than light conditions (Mukai and Lim, 2011). This information suggests that African catfish depend primarily on chemosensory organs for their feeding (Mukai *et al*., 2008; Mukai and Lim, 2011). However, Lee *et al*. (2014) confirmed that the African catfish juveniles have colour vision, which can increase the efficiency of detecting and catching feed by vision under certain light wavelengths. As different colours have different contrasts against a background colour, a high contrast leads to the higher visibility of feed and thus better feed consumption (Kawamura *et al*., 2010, 2016; El-Sayed and El-Ghobashy, 2011). Hence, high growth rates under yellow light were observed in the present study because the studied juveniles may have been better able to feed under this light wavelength.

Conclusion

In conclusion, our results show that the African catfish juveniles were sensitive towards different light wavelengths. The growth of this fish species increased when reared under yellow light.

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