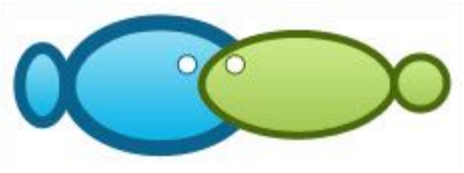

Effects of light intensity on growth and survival rate of freshwater prawn (*Macrobrachium rosenbergii*) at larvae and postlarvae stages in biofloc system

Chau T. Tao, Tran N. D. Khoa, Pham M. Truyen, Nguyen V. Hoa, Cao M. An, Tran N. Hai

College of Aquaculture and Fisheries, Cantho University, Cantho City, Vietnam.
Corresponding author: T. N. Hai, tnhai@ctu.edu.vn

Abstract. Light is considered as a key ecological factor affecting the growth, development and survival of aquatic organisms. This study evaluated the effects of light intensity on growth and survival rate of freshwater prawn larvae (*Macrobrachium rosenbergii*) reared in biofloc system at 17.5 of C/N ratio. The experiment consisted of five light intensities of 1,000 lux (T1), 10,000 lux (T2), 20,000 lux (T3), 30,000 lux (T4) and natural light (control) in triplicate. The larvae were stocked in 250-L tanks at 12 ‰ of water salinity and 60 inds L^{-1} of density. The rearing systems were exposed to light at 12Dark:12Light of photoperiod and lasted for 32 days. The results showed that the water quality, microbial counts, and floc performance were maintained in suitable ranges for development of *M. rosenbergii* larvae. Floc contained 29.37-30% of protein, 2.37-2.63% of lipid and 28.1-28.46% of ash. After 32 days, the T3 treatment (20,000 lux) demonstrated the most efficiency in larval metamorphosis, growth (10.94 mm), survival (58.23%) and productivity (34,919 ind m^{-3}) while the larvae at 1,000 light lux showed the lowest values ($p < 0.05$). It suggested that application of biofloc technology with 20,000 exposed light lux for freshwater prawn larvae could help to improve water quality and larval performance.
Key Words: biofloc, growth performance, larviculture, light intensity, *Macrobrachium rosenbergii*.

Introduction. Biofloc technology (BFT) has recently attracted attention as a sustainable solution in aquaculture which is responsible for improving water quality, supplementing natural food, and enhancing growth and health of cultured organism (Castro-Nieta et al 2012; Li et al 2018; Khoa et al 2020). Biofloc microorganisms flutuated among different systems with various temperature, salinity, pH, light quality, the intensity of vertical mixing, and the type of organic carbon (García-Ríos et al 2019; Samocha et al 2019). In which, light intensity plays an important role in the performance, composition and abundance of microorganisms in aquaculture systems (Llario et al 2019). Besides, previous studies highlighted that light intensity also affects growth performance, metamephorsis and survival of aquatic animals (Didrikas & Hansson 2009; Guo et al 2013; Chen et al 2021). Therefore, it requires to determine the appropriate light intensity for both biofloc and cultured species in the system.

Freshwater prawn (*Macrobrachium rosenbergii*) is one of important crustacean species produced in many tropical and subtropical countries worldwide (Thanh et al 2009). In Vietnam, *M. rosenbergii* was traditionally cultured in the Mekong Delta in both freshwater and brackish water regions and was considered as a high priority species for aquaculture development program (Vietnam Directorate of Fisheries 2020). Therefore, the supplied capacity of good quality and high quantity of postlarvae for stustaiable development of *M. rosenbergii* culture was questioned. The hatchery technology for *M. rosenbergii* was recently improved in rearing protocols. Besides, traditional protocols have been applied effectively such as opened system (exchange water), recirculating system, green water, etc. (Phuong et al 2003). Recently, biofloc technology was developed for *M. rosenbergii* larviculture and showed high potential application (Tao et al

2021; Truyen et al 2021). This present study aims to determine the appropriate light intensity for *M. rosenbergii* larviculture in biofloc system. The results from this study may support optimizing the hatchery technology for *M. rosenbergii.*

Material and Method

Location and the period of study. This study was conducted on College of Aquaculture, Cantho University, Vietnam during November to December 2020.

Larvae sources. Ovigerous healthy females of *M. rosenbergii* with grey eggs (50-80 g ind^{-1}) were collected from a farm (Can Tho city, VietNam) and transferred to incubated tank (500 L) at 7 ‰ of salinity. After hatching, strong photopositive larvae were collected and used for the experiment.

Water treatment and biofloc creation. Brine water (90 ‰) was diluted with tap water to achieve 12 ‰ of salinity before treating with chlorine (50 g m^{-3}) and continuous aeration. Sodium bicarbonate ($NaHCO_3$) was applied to stabilize alkalinity at 120 mg $CaCO_3$ L^{-1} throughout the cultured period. Thereafter, water was filtered through a microfilter bar (1 µm mesh size) into the larvae tanks.

For biofloc performance, refined sugar (55.54% C) was applied as a carbon source at 17.5 of C/N ratio (Nghi et al 2020; Truyen et al 2021). Sugar was dissolved in warm water (60^oC) at a ratio of 1:3, stired and incubated with strong aeration for 48 h at room temperature, then added into the larvae tanks. From stage 4 of freshwater prawn, sugar was daily applied into rearing tanks following the protocol described by Avnimelech (2014), while larvae were fed daily with Lansy PL feed (INVE, Belgium) containing of 48% protein.

Experimental design and management. The experiment was randomly set up in 0.25 m^3 composite tanks in triplicate consisting of 5 treatments of light intensity of 1,000 lux (T1), 10,000 lux (T2), 20,000 lux (T3), 30,000 lux (T4) and natural light (control) indoor under transparent roof). *M. rosenbergii* larvae were stocked at 60 inds L^{-1} in tanks at water salinity of 12 ‰ . For the treatments T1-T4, the tanks were set up in dark room and exposed to compact lights with a photoperiod of 12D:12L. The experiment lasted for 32 days. The feeding regimes for larvae are presented in Table 1.

Table 1

Feeding regimes for giant freshwater prawn larvae

Larval stage	*Feed type*	*Amount*	*Frequency*
Stage 1	No feeding	-	-
Stage 2-3	*Artemia* nauplii	1 ind mL^{-1}	Twice a day (7 h and 17 h)
Stage 4-5	Lansy PL	1 g m^{-3}	3 times/day (8h, 11h and 14h)
	Artemia nauplii	3 ind mL^{-1}	Once a day (17h)
Stage 6-8	Lansy PL	1.5 g m^{-3}	3 times/day (8h, 11h and 14h)
	Artemia nauplii	3 ind mL^{-1}	Once a day (17h)
Stage 9 - PL15	Lansy PL	2 g m^{-3}	3 times/day (8h, 11h and 14h)
	Artemia nauplii	4 ind mL^{-1}	Once a day (17h)

Water quality parameters. During the experimental time, water temperature and pH were measured twice a day using a HI-98127 Multi-Parameter Waterproof Meter (HANNA Instruments, Ltd.). Alkalinity, total ammonia (TAN), and nitrites measurements were performed every 3 days according to the standard methods (APHA 2005).

Total bacteria and Vibrio spp. count. Every 8 days, water samples were collected to quantify total bacteria and *Vibrio* spp. according to methods described Huys (2002). Besides, at the end of the experiment, the total bacteria and *Vibrio* spp. in biofloc and prawn were also checked.

Biofloc parameters. At the stage of PL-5, PL-10, and PL-15 of *M. rosenbergii* larvae, the floc volume was measured based on the sedimentation of the flocs contained in a 1 L water sample after 15-20 min in an Imhoff cone (Avnimelech 2014). A total of 10 floc samples from each tank was collected and recorded for floc particle sizes under a Nikon ECLIPSE Ti2 microscope with a DS-Qi2 camera (Nikon Corporation, Tokyo, Japan). Zooplankton and phytoplankton compositions were determined according to keys from Shirota (1966) and Agrawal & Gopal (2013). At the end of the experiment, the proximate compositions in the percentage of protein, lipid, and ash from the dry weights of the biofloc were analyzied following AOAC (2016).

Zootechnical parameters. A total of 10 larvae or postlarvae of freshwater prawn from each tank was sampled every 3 days to esimate the larval stage index (LSI). Body length of prawn was randomly recorded from 30 prawns of each treatment at stage 1, 5, 11, PL1, and PL15. Prawn survival rate and biomass were determined at the end of the experiment:

$$SR\ (\%) = \frac{\text{Total number of PL harvested}}{\text{Total number of larvae stocked}} \times 100$$

$$\text{Biomass (ind } L^{-1}) = \text{number of PL collected/tank volume}$$

Statistical analyses. Data was presented as mean±SD and subjected to one-way ANOVA using IBMSPSS Statistics 20.0 software for windows (IBM Corporation, NY, USA). Duncan's multiple range tests were used to determine the differences among treatment means at a significance level of $p < 0.05$.

Results and Discussion

Water quality parameters. Average values of temperature, pH, alkalinity, TAN, and nitrite are presented in Table 2. There were no significant differences ($p > 0.05$) among treatments in terms of water temperature, pH, alkalinity and nitrite. In which, water temperature daily ranged from 28.4 to 29.1°C, pH was from 7.96 to 8.14, and alkalinity was maintained at 115 mg $CaCO_3$ L^{-1}. The nitrite concentration was recorded at low levels (0.16-0.20 mg L^{-1}) while the highest level of TAN was observed in the control treatment (1.17 mg L^{-1}) ($p < 0.05$). The results in water quality remained within the ranges reported as suitable for the larviculture of freshwater prawn (Tao et al 2021). Importantly, it indicated that the application of BFT in *M. rosenbergii* hatchery could help to improve water quality without water exchange due to the compounds of nitrite and ammonia were removed by the microbial community (Ebeling et al 2006).

Table 2

Water quality parameters among treatments during the experimental period

Parameter		*Treatment*				
		1,000 Lux	*10,000 Lux*	*20,000 Lux*	*30,000 Lux*	*Control*
Temperature (°C)	8 am	28.4±0.7	28.5±0.8	28.8±0.7	28.9±0.7	29.0±0.9
	2 pm	28.5±0.2	28.5±0.2	29.0±0.5	28.9±0.7	29.1±0.5
pH	8 am	8.06±0.09	8.08±0.10	8.05±0.10	8.06±0.10	7.96±0.13
	2 pm	8.11±0.10	8.14±0.11	8.12±0.10	8.13±0.09	8.03±0.13
Alkalinity (mg $CaCO_3$ L^{-1})		115.8±3.7	115.3±4.2	115.7±3.1	115.4±3.5	114.9±4.1
TAN (mg L^{-1})		1.05±0.42[a]	1.02±0.02[a]	1.03±0.03[a]	1.04±0.02[a]	1.17±0.05[b]
NO_2^- (mg L^{-1})		0.20±0.05[a]	0.19±0.02[a]	0.16±0.01[a]	0.17±0.03[a]	0.18±0.01[a]

Values in the same row with different superscripts are significantly different ($p < 0.05$).

Light intensity. Light lux intensity among treatments is recorded in Table 3. In the treatments applied artificial light (T1, T2, T3, and T4), light intensity was controlled according to trial levels while the control treatment showed a fluctuation of light intensity through the daytime (146-27,033 lux). Previous studies reported that light quality

(spectra, intensity, and photoperiod) significantly affected the growth, metamorphosis and survival rate of crustaceans including *M. rosenbergii* (Wei et al 2021) as well as the structure and abundance of the microbial community in the biofloc system (Khoa et al 2020, 2021).

Table 3

Light intensity among treatments during the experiment

Time	*Treatment*				
	1,000 Lux	*10,000 Lux*	*20,000 Lux*	*30,000 Lux*	*Control*
6h	1.006 ± 1.0^{b}	10.003 ± 1.0^{c}	20.003 ± 2.5^{d}	30.002 ± 1.5^{e}	436 ± 3.6^{a}
9h	1.006 ± 1.2^{a}	10.002 ± 0.6^{c}	20.003 ± 1.0^{d}	30.001 ± 0.6^{e}	$8,146 \pm 3.6^{b}$
12h	1.005 ± 0.6^{a}	10.004 ± 0.6^{b}	20.002 ± 1.2^{c}	30.001 ± 1.2^{e}	$27,033 \pm 4.0^{d}$
15h	1.003 ± 1.5^{a}	10.003 ± 0.1^{b}	20.002 ± 1.7^{d}	30.002 ± 1.7^{e}	$15,756 \pm 2.0^{c}$
18h	1.005 ± 1.5^{b}	10.004 ± 1.7^{c}	20.001 ± 1.0^{d}	30.000 ± 1.5^{e}	146 ± 1.5^{a}

Values in the same row with different superscripts are significantly different ($p < 0.05$).

Floc volume and sizes. Floc volume and sizes among treatments tend to increase gradually throughout the experiment (Table 4). The T1 treatment (1,000 lux) showed the lowest volume (0.67-1.8 mL L^{-1}) and sizes (0.14-0.27 mm in width and 0.16-0.48 mm in length) of floc ($p < 0.05$). In contrast, T3, T4 and control treatment were recored with significant difference in floc volume (1.07-3.03 mL L^{-1}) compared to others ($p < 0.05$). In biofloc systems, De Schryver et al (2008) reported that the biofloc uptake potential and digestibility by the aquatic animals as well as the floc nutrient values are related to the biofloc volume and size. Moreover, floc size plays an important role in recycling nutrients and maintaining water quality (Ekasari et al 2014). In addition, the particle size or floc abundance seems to affect the distribution and interaction of nitrifying microorganisms, which significantly influence the nitrification process (Souza et al 2019).

Table 4

Floc volume and sizes throughout the experiment

Parameter		*Treatment*				
		1,000 Lux	*10,000 Lux*	*20,000 Lux*	*30,000 Lux*	*Control*
Volume (mL L^{-1})	PL5	0.67 ± 0.10^{a}	1.33 ± 0.15^{b}	1.73 ± 0.15^{c}	1.90 ± 0.20^{c}	1.07 ± 0.15^{b}
	PL10	1.30 ± 0.20^{a}	2.10 ± 0.20^{bc}	2.33 ± 0.15^{cb}	2.47 ± 0.15^{d}	1.93 ± 0.15^{b}
	PL15	1.80 ± 0.10^{a}	2.47 ± 0.23^{b}	2.83 ± 0.12^{c}	3.03 ± 0.15^{c}	2.70 ± 0.26^{bc}
Width (mm)	PL5	0.14 ± 0.01^{a}	0.16 ± 0.01^{b}	0.15 ± 0.01^{b}	0.16 ± 0.01^{b}	0.16 ± 0.01^{b}
	PL10	0.21 ± 0.02^{a}	0.31 ± 0.02^{b}	0.28 ± 0.01^{b}	0.32 ± 0.06^{b}	0.28 ± 0.02^{b}
	PL15	0.27 ± 0.01^{a}	0.37 ± 0.05^{b}	0.38 ± 0.07^{b}	0.41 ± 0.03^{b}	0.35 ± 0.04^{b}
Length (mm)	PL5	0.16 ± 0.01^{a}	0.23 ± 0.01^{b}	0.26 ± 0.01^{b}	0.24 ± 0.03^{b}	0.25 ± 0.02^{b}
	PL10	0.37 ± 0.02^{a}	0.49 ± 0.04^{b}	0.52 ± 0.02^{b}	0.46 ± 0.07^{b}	0.46 ± 0.03^{b}
	PL15	0.48 ± 0.02^{a}	0.55 ± 0.02^{b}	0.58 ± 0.03^{bc}	0.63 ± 0.02^{c}	0.56 ± 0.07^{bc}

Values in the same row with different superscripts are significantly different ($p < 0.05$).

Plankton composition in flocs. The community of phytoplankton and zooplankton among treatments was mainly recorded with Bacillariophyta, Euglenophyta, Rotifera, Dinophyta, Chlorophyta and Protozoa. The phytoplankton and zooplankton structures in number of species are presented in Figure 1. In which, Chlorophyta and Bacillariophyta had the highest relative abundance, followed by Rotifera. Previous studies highlighted that the floc dominated by microalgae and bacteria could contribute more benefits for shrimp performance and water quality (Khoa et al 2020).

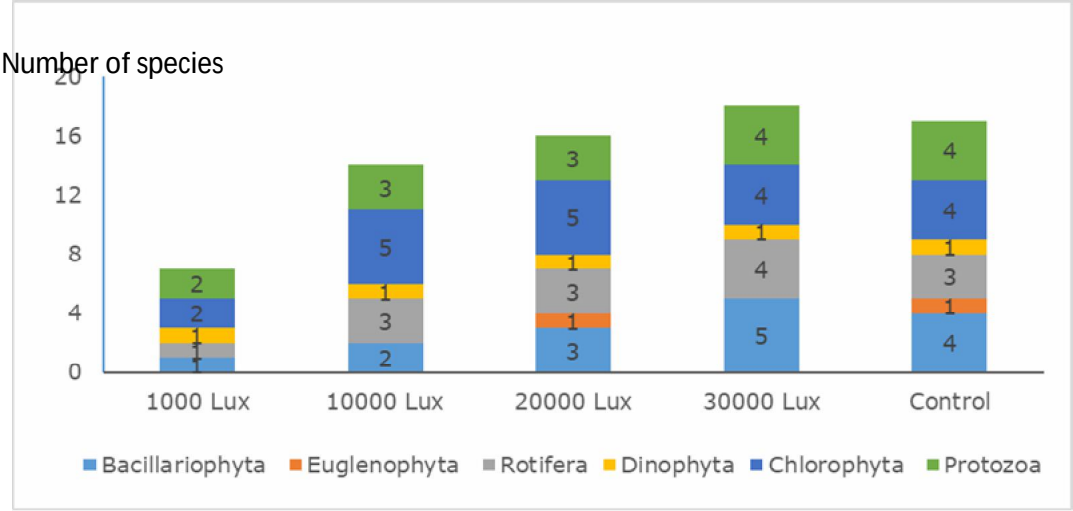

Figure 1. The biofloc compositios in number of phytoplankton and zooplankton species among treatments.

Floc biochemical compositions. After 32 days of rearing, floc proximate compositions among treatments were evaluated (Table 5). No significant difference in lipid (2.37-2.63%) and ash (28.10–28.46 %) was observed among treatments ($p > 0.05$). However, protein in T3, T4 and control treatment ranged from 29.64 to 30% and were statitiscally higher than T1 (29.37%) and T2 (29.5%) ($p < 0.05$). The bioflocs serve as natural nutrition in a form of natural live food continuously available in the system (Durigon et al 2020). These results were similar to data from a study of Khoa et al (2021), but were significantly different compared to Tao et al (2021). It might be related to the difference in C/N ratio, floc compositions, salinity and microbial community (Khoa et al 2020).

Table 5

Floc proximate composition from different treatments

Treatment	*Protein (%)*	*Lipid (%)*	*Ash (%)*
1,000 Lux	29.37 ± 0.15^{a}	2.47 ± 0.23^{a}	28.10 ± 0.26^{a}
10,000 Lux	29.50 ± 0.20^{a}	2.37 ± 0.06^{a}	28.46 ± 0.21^{a}
20,000 Lux	30.00 ± 0.26^{b}	2.50 ± 0.20^{a}	28.43 ± 0.21^{a}
30,000 Lux	29.70 ± 0.36^{ab}	2.63 ± 0.12^{a}	28.40 ± 0.20^{a}
Control	29.64 ± 0.30^{ab}	2.40 ± 0.10^{a}	28.37 ± 0.15^{a}

Values in the same colunm with different superscripts are significantly different ($p < 0.05$).

Total bacteria and Vibrio spp. density in water, flocs and prawn. The microbial counts in water, floc and prawn samples are presented in Tables 6, 7, 8, and 9. The results indicated that the exposure to light intensity did not affect significantly the total bacteria density and *Vibrio* spp. density in rearing water, floc, and prawn ($p > 0.05$). Accordingly, among treatments, total bacteria density at the first sampling (0.37-0.73 x 10^4 CFU mL^{-1}) and *Vibrio* spp. (0.23-0.43 x 10^2 CFU mL^{-1}), these parameters tended to increase gradually until the end of the experiment (2.4-3.03 x 10^4 CFU mL^{-1} and 2.23-2.50 x 10^2 CFU mL^{-1}, respectively) (Tables 6 and 7). Moreover, floc samples presented 12.10-14.67x10^4 CFU g^{-1} of total bacteria and 1.53-1.83 x 10^2 CFU g^{-1} of *Vibrio* spp. (Table 8) while prawn samples were recorded with 2.83-4.23 x 10^4 CFU g^{-1} of total bacteria and 0.3-0.53 x 10^2 CFU g^{-1} of *Vibrio* spp. (Table 9). Ray et al (2011) remarked that microbial communities in BFT system play an essential role in cycling of nutrients and providing of supplemental nutrition. In this study, water quality parameters were significantly improved reflecting the effective nitrification process.

Table 6

Total bacteria (10^4 CFU mL^{-1}) in rearing water among treatments

Sampling time	*Treatment*				
	1,000 Lux	*10,000 Lux*	*20,000 Lux*	*30,000 Lux*	*Control*
1	0.50 ± 0.20^a	0.37 ± 0.25^a	0.73 ± 0.21^a	0.37 ± 0.31^a	0.43 ± 0.15^a
2	1.50 ± 0.35^a	1.40 ± 0.46^a	1.93 ± 0.15^a	1.30 ± 0.20^a	1.70 ± 0.52^a
3	1.73 ± 0.23^a	2.27 ± 0.40^a	2.10 ± 0.10^a	1.77 ± 0.25^a	2.00 ± 0.44^a
4	2.47 ± 0.38^a	2.60 ± 0.62^a	2.40 ± 0.36^a	2.53 ± 0.38^a	3.03 ± 0.57^a

Values in the same row with different superscripts are significantly different ($p < 0.05$).

Table 7

Vibrio spp. count in rearing water (10^2 CFU mL^{-1}) among treatments

Sampling time	*Treatment*				
	1,000 Lux	*10,000 Lux*	*20,000 Lux*	*30,000 Lux*	*Control*
1	0.33 ± 0.15^a	0.43 ± 0.25^a	0.30 ± 0.17^a	0.27 ± 0.21^a	0.23 ± 0.06^a
2	0.93 ± 0.25^a	0.97 ± 0.15^a	1.00 ± 0.20^a	1.17 ± 0.35^a	0.80 ± 0.36^a
3	1.77 ± 0.25^a	1.37 ± 0.21^a	1.53 ± 0.42^a	1.63 ± 0.51^a	1.36 ± 0.31^a
4	2.30 ± 0.20^a	2.23 ± 0.25^a	2.50 ± 0.26^a	2.33 ± 0.25^a	2.47 ± 0.15^a

Values in the same row with different superscripts are significantly different ($p < 0.05$).

Table 8

Total bacteria density (10^4 CFU g^{-1}) and *Vibrio* spp. (10^2 CFU g^{-1}) in floc samples

Parameter	*Treatment*				
	1,000 Lux	*10,000 Lux*	*20,000 Lux*	*30,000 Lux*	*Control*
Total bacteria	12.10 ± 0.62^a	12.53 ± 1.11^a	14.67 ± 0.97^a	14.37 ± 2.94^a	14.23 ± 2.43^a
Vibrio spp.	1.83 ± 0.58^a	1.70 ± 0.36^a	1.53 ± 0.32^a	1.77 ± 0.15^a	1.60 ± 0.35^a

Values in the same row with different superscripts are significantly different ($p < 0.05$).

Table 9

Total bacteria density (10^4 CFU g^{-1}) and *Vibrio* spp. (10^2 CFU g^{-1}) in prawn samples

Parameter	*Treatment*				
	1,000 Lux	*10,000 Lux*	*20,000 Lux*	*30,000 Lux*	*Control*
Total bacteria	3.17 ± 0.85^a	3.33 ± 0.85^a	3.16 ± 0.66^a	4.23 ± 0.75^a	2.83 ± 0.42^a
Vibrio spp.	0.40 ± 0.20^a	0.53 ± 0.15^a	0.43 ± 0.06^a	0.33 ± 0.15^a	0.30 ± 0.10^a

Values in the same row with different superscripts are significantly different ($p < 0.05$).

Larval stage index (LSI) of freshwater prawn larvae. Throughout the experiment, the larvae exposed to light lux density less than 10,000 lux (T1 and T2) showed significantly lower LSI values compared to others after 21 days ($p < 0.05$). A similar trend in larval metamorphosis was observed in T3, T4 and control treatment ($p > 0.05$) (Table 10). These results suggested that natural sun light and artificial light (20,000-30,000 lux) were effective for larval metamorphosis of freshwater prawn larvae. In crustaceans, especially on shrimp and crab, light spectra and intensity aided the growth performance by increasing activity or molting rates (Li et al 2011; Guo et al 2013) while photoperiodicity showed effects on shrimp production and behavior (Wang et al 2004; De los Santos-Romero et al 2017).

Table 10

Larval stage index (LSI) of *M. rosenbergii* larvae

Day	Treatment				
	1,000 lux	*10,000 Lux*	*20,000 Lux*	*30,000 Lux*	*Control*
3	2.27 ± 0.06^{a}	2.43 ± 0.06^{ab}	2.60 ± 0.10^{b}	2.60 ± 0.10^{b}	2.57 ± 0.15^{b}
6	4.73 ± 0.40^{a}	4.93 ± 0.40^{ab}	5.30 ± 0.30^{b}	5.37 ± 0.15^{b}	5.43 ± 0.06^{b}
9	5.43 ± 0.12^{a}	6.10 ± 0.60^{ab}	6.50 ± 0.50^{b}	6.67 ± 0.46^{b}	6.80 ± 0.20^{b}
12	6.93 ± 0.15^{a}	7.00 ± 0.10^{a}	7.93 ± 0.40^{b}	8.20 ± 0.44^{b}	7.80 ± 0.10^{b}
15	7.83 ± 0.25^{a}	8.23 ± 0.06^{b}	8.77 ± 0.15^{c}	8.50 ± 0.10^{b}	8.33 ± 0.06^{b}
18	10.30 ± 0.20^{a}	10.43 ± 0.29^{ab}	10.87 ± 0.15^{c}	10.70 ± 0.10^{b}	10.73 ± 0.06^{b}
21	10.97 ± 0.15^{a}	11.10 ± 0.10^{a}	11.57 ± 0.06^{b}	11.47 ± 0.25^{b}	11.43 ± 0.06^{b}

Values in the same row with different superscripts are significantly different ($p < 0.05$).

Length (mm) of freshwater prawn larvae and post larvae. From stage 5 of larval development, the T1 treatment showed the lowest values in body length, while larval length in the natural light and 10,000-30,000 lux light treatments were significantly higher than T1. In which, the PL-15 reached the highest length (10.94±0.06 mm) at 20,000 Lux (Table 11). Light intensity and photoperiodicity can regulate the growth during early life stages of aquatic animals through its effect on feeding rhythms and influence on feeding behavior. Changes in the light quality could lead to changes in appetite, food intake, and feed conversion efficiency in freshwater shrimps and thus have effects on growth performance (Espinosa-Chaurand 2013).

Table 11

Length (mm) of freshwater prawn larvae and post larvae

Larval stage	Treatment				
	1,000 lux	*10,000 Lux*	*20,000 Lux*	*30,000 Lux*	*Control*
Stage 1	2.13 ± 0.09^{a}	2.13 ± 0.09^{a}	2.13 ± 0.09^{a}	2.13 ± 0.09^{a}	2.13 ± 0.09^{a}
Stage 5	2.59 ± 0.17^{a}	2.84 ± 0.10^{b}	2.93 ± 0.02^{b}	2.92 ± 0.02^{b}	2.98 ± 0.04^{b}
Stage 11	7.86 ± 0.16^{a}	7.98 ± 0.07^{a}	8.20 ± 0.04^{b}	8.18 ± 0.02^{b}	8.17 ± 0.12^{b}
PL-1	8.04 ± 0.05^{a}	8.30 ± 0.03^{b}	8.59 ± 0.08^{c}	8.48 ± 0.02^{c}	8.47 ± 0.14^{c}
PL-15	9.86 ± 0.20^{a}	10.27 ± 0.03^{b}	10.94 ± 0.06^{c}	10.39 ± 0.22^{b}	10.56 ± 0.25^{b}

Values in the same row with different superscripts are significantly different ($p < 0.05$).

Survival rate and productivity of PL-15. There is a significant difference in survival and productivity of PL-15 of *M. rosenbergii* (Table 12). The highest survival rate (58.23%) and productivity (34,919 ind m^{-3}) were observed in the T3 treatment, while the lowest values were at 1,000 lux (9.07% and 5,458 ind m^{-3}, respectively). The photoperiodic control of many important physiological functions physiological functions, endocrine control, and even cannibalism in crustaceans were documented (Hecht & Pienaar 1993; Brito et al 2001; Vega-Villasante et al 2015). At early stages of decapods, the changes in light intensity and day length could result in the change of feeding habits or digestive enzyme activity (Deering et al 1995; Bermudes & Ritar 2008; Matsuda et al 2012). Accordingly, light intensity and day length affected physiological functions, feeding behaviors, and mobility of aquatic organisms, hence, will affect growth and survival (Gardner & Maguire 1998).

Table 12

Survival rate and productivity of PL-15

Parameter	Treatments				
	1,000 Lux	*10,000 Lux*	*20,000 Lux*	*30,000 Lux*	*Control*
Survival (%)	9.07 ± 0.45^{a}	30.00 ± 2.17^{b}	58.23 ± 2.74^{d}	49.03 ± 3.23^{c}	48.97 ± 2.31^{c}
Productivity (ind m^{-3})	$5,458\pm275^{a}$	$18,011\pm1,299^{b}$	$34,919\pm1,661^{d}$	$29,411\pm1.936^{c}$	$29,385\pm1,388^{c}$

Values in the same row with different superscripts are significantly different ($p < 0.05$).

Conclusions and recommendations. The results from this study demonstrated that the application of BFT in larviculture of freshwater prawn could maintain good water quality. It also indicated that the constant light lux intensity at 20,000 lux (12D:12L) showed the best results in floc performance, metamorphosis, survival and productivity of *M. rosenbergii* larvae. Further studies are required to verify the beneficial effects of biofloc on physiological responses and healthy culture of freshwater prawn, and on how to manipulate microbial communities and active compounds of biofloc under different culture conditions.

Acknowledgements. This study belongs to the Vietnamese ODA F-2 project "Green Technology Innovation for Aquaculture," which is funded by the Can Tho University Improvement Project VN14-P6, supported by a Japanese ODA loan.

Conflict of interest. The authors declare that there is no conflict of interest.

References

Agrawal A., Gopal K., 2013 Analysis of phytoplankton and zooplankton: qualitative and quantitative. In: Biomonitoring of water and waste water. Gopal A. A. (ed), Springer India, pp. 33-40.

American Public Health Association (APHA), 2005 Standard methods for the examination of water and wastewater. 21st edition. APHA, Washington, DC.

AOAC, 2016 Official methods of analysis of AOAC International. 20th edition. AOAC International, 3172 pp.

Avnimelech Y., 2014 Biofloc technology - a practical guidebook. 3rd edition. The World Aquaculture Society, 258 pp.

Bermudes M., Ritar A. J., 2008 Response of early stage spiny lobster *Jasus edwardsii* phyllosoma larvae to changes in temperature and photoperiod. Aquaculture 281(1-4):63-69.

Brito R., Rosas C., Chimal M. E., Gaxiola G., 2001 Effect of different diets on growth and digestive enzyme activity in *Litopenaeus vannamei* (Boone, 1931) early post-larvae. Aquaculture Research 32(4):257-266.

Castro-Nieta L. M., Castro-Barrera T., De Lara Andrade R., Castro-Mejia J., Castro-Mejia G., 2012 Biofloc systems: a technological breakthrough in aquaculture. Revista Digital del Departamento El Hombre y su Ambiente 1(1):1-5.

Chen S., Migaud H., Shi C., Song C., Wang C., Ye Y., Ren Z., Wang H., Mu C., 2021 Light intensity impacts on growth, molting and oxidative stress of juvenile mud crab *Scylla paramamosain*. Aquaculture 545:737159.

De los Santos-Romero R., García-Guerrero M., Vega-Villasante F., Cortés-Jacinto E., Nolasco-Soria H., 2017 Effect of photoperiod and temperature on growth and activity of digestive enzymes in juveniles of the long-arm river shrimp *Macrobrachium tenellum* (Smith, 1871) (Caridea: Palaemonidae). Journal of Crustacean Biology 37(4):445-452.

De Schryver P., Crab R., Defoirdt T., Boon N., Verstraete W., 2008 The basics of bio-flocs technology: the added value for aquaculture. Aquaculture 277(3-4):125-137.

Deering M. J., Fielder D. R., Hewitt D. R., 1995 Effects of temperature on growth and protein assimilation in juvenile leader prawns *Penaeus monodon*. Journal of the World Aquaculture Society 26(4):465-468.

Didrikas T., Hansson S., 2009 Effects of light intensity on activity and pelagic dispersion of fish: studies with a seabed-mounted echosounder. ICES Journal of Marine Science 66(2):388-395.

Durigon E. G., Lazzari R., Uczay J., Luis de Alcantara Lopes D., Tomas Jeronimo G., Sgnaulin T., Coelho Emerenciano M. G., 2020 Biofloc technology (BFT): adjusting the levels of digestible protein and digestible energy in diets of Nile tilapia juveniles raised in brackish water. Aquaculture and Fisheries 5(1):42-51.

Ebeling J. M., Timmons M. B., Bisogni J. J., 2006 Engineering analysis of the stoichiometry of photoautotrophic, autotrophic, and heterotrophic removal of ammonia-nitrogen in aquaculture systems. Aquaculture 257(1-4):346-358.

Ekasari J., Angela D., Waluyo S. H., Bachtiar T., Surawidjaja E. H., Bossier P., De Schryver P., 2014 The size of biofloc determines the nutritional composition and the nitrogen recovery by aqua- culture animals. Aquaculture 426-427:105-111.
Espinosa Chaurand L. D., 2013 La actividad enzimática digestiva y su aplicación nutricional en el langostino *Macrobrachium tenellum* (Smith, 1871). Doctoral thesis, Universidad de Guadalajara, México, 76 pp. [in Spanish]
García-Ríos L., Miranda-Baeza A., Coelho-Emerenciano M. G., Huerta-Rábago J. A., Osuna-Amarillas P., 2019 Biofloc technology (BFT) applied to tilapia fingerlings production using different carbon sources: emphasis on commercial applications. Aquaculture 502:26-31.
Gardner C., Maguire G. B., 1998 Effect of photoperiod and light intensity on survival, development and cannibalism of larvae of the Australian giant crab *Pseudocarcinus gigas* (Lamarck). Aquaculture 165(1-2):51-63.
Guo B., Wang F., Li Y., Dong S., 2013 Effect of periodic light intensity change on the molting frequency and growth of *Litopenaeus vannamei*. Aquaculture 396-399:66-70.
Hecht T., Pienaar A. G., 1993 A review of cannibalism and its implications in fish larviculture. Journal of the World Aquaculture Society 24(2):246-261.
Huys G., 2002 Preservation of bacteria using commercial cryopreservation systems. Standard Operation Procedure Asiaresist Pres, 6 pp.
Khoa T. N. D., Tao C. T., Khanh L. V., Hai T. N., 2020 Super-intensive culture of white leg shrimp (*Litopenaeus vannamei*) in outdoor biofloc systems with different sunlight exposure levels: emphasis on commercial applications. Aquaculture 524:735277.
Khoa T. N. D., Tao C. T., Hoa N. V, Hai T. N., 2021 Effects of carbohydrate addition time on a biofloc system for white leg shrimp (Litopenaeus vannamei) at larvae and post larvae stage. AACL Bioflux 14(5):2929-2938.
Li J., Liu G., Li C., Deng Y., Tadda M. A., Lan L., Zhu S., Liu D., 2018 Effects of different solid carbon sources on water quality, biofloc quality and gut microbiota of Nile tilapia (*Oreochromis niloticus*) larvae. Aquaculture 495:919-931.
Li X., Li Z., Liu J., Zhang T., Zhang C., 2011 Effects of light intensity on molting, growth, precocity, digestive enzyme activity, and chemical composition of juvenile Chinese mitten crab *Eriocheir sinensis*. Aquaculture International 19:301-311.
Llario F., Rodilla M., Escrivá J., Falco S., Sebastiá-Frasquet M. T., 2019 Phytoplankton evolution during the creation of a biofloc system for shrimp culture. International Journal of Environmental Science and Technology 16(1):211-222.
Matsuda H., Takenouchi T., Yamakawa T., 2012 Effect of photoperiod and temperature on ovarian development and spawning of the Japanese spiny lobster *Panulirus japonicus*. Aquaculture 205(3):385-398.
Nghi L. T., Truyen P. M., Tao C. T., Hoa N. V., Hai T. N., 2020 [Effects of carbon sources on growth performance and survival rate of larval rearing of the freshwater prawn (*Macrobrachium rosenbergii*) by biofloc technology]. Journal of Vietnam Agricultural Science and Technology 5(114):117-123. [in Vietnamese]
Phuong N. T., Hai T. N., Hien T. T. T., Wilder M. N., 2003 [Principle and production technique for freshwater prawn (*Macrobrachium rosenbergii*)]. Agriculture Publishing House, Ho Chi Minh city, 127 pp. [in Vietnamese]
Ray A. J., Dillon K. S., Lotz J. M., 2011 Water quality dynamics and shrimp (*Litopenaeus vannamei*) production in intensive, mesohaline culture systems with two levels of biofloc management. Aquacultural Engineering 45(3):127-136.
Samocha T. M., Prangnell D. I., Castro L. F., 2019 Biofloc. In: Sustainable biofloc systems for marine shrimp. Samocha T. M. (ed), Academic Press, pp. 29-36.
Shirota A., 1966 The plankton of South Viet-Nam - fresh water and marine plankton. Overseas Technical Cooperation Agency, Japan, 162 pp.
Souza J., Cardozo A., Wasielesky W., Abreu P., 2019 Does the biofloc size matter to the nitrification process in Biofloc Technology (BFT) systems? Aquaculture 500:443-450.
Tao C. T., Truyen P. M., Khanh L. V, Terahara T., Hai T. N., Hoa N. V., 2021 The influence of feeding reduction on the survival and growth of the larvae and postlarvae of freshwater prawn (*Macrobrachium rosenbergii*): an applied biofloc technology study. AACL Bioflux 14(5):2650-2661.

Thanh N. M., Ponzoni R. W., Nguyen N. H., Vu N. T., Barnes A., Mather P. B., 2009 Evaluation of growth performance in a diallel cross of three strains of giant freshwater prawn (*Macrobrachium rosenbergii*) in Vietnam. Aquaculture 287:75-83.
Truyen P. M., Tao C. T., Hoa N. V., Hai T. N., 2021 [Study on nursing giant freshwater prawn (*Macrobrachium rosenbergii*) larvae applying biofloc technology by supplementation of sugar at different stages]. Journal of Sciences, Can Tho University 57(2B):177-183. [in Vietnamese]
Vega-Villasante F., Martínez-Ochoa E. F., García-Guerrero M. U., Arrona-Ortiz J. D., 2015 Effect of different light intensities on expression of chromatophores, growth and survival in juvenile *Macrobrachium tenellum*. Latin American Journal of Aquatic Research 43(1):255-261.
Vietnam Directorate of Fisheries, 2020 [Project on development of production and export of giant freshwater prawn]. Available at: https://tongcucthuysan.gov.vn/en-us/Home. Accessed: October, 2021. [in Vietnamese]
Wang F., Dong S., Dong S., Huang G., Zhu C., Mu Y., 2004 The effect of light intensity on the growth of Chinese shrimp *Fenneropenaeus chinensis*. Aquaculture 234(1):475-483.
Wei J., Tian L., Wang Y., Yu L., Zhu X., 2021 Effects of salinity, photoperiod, and light spectrum on larval survival, growth, and related enzyme activities in the giant freshwater prawn, *Macrobrachium rosenbergii*. Aquaculture 530:735794.

Received: 11 November 2021. Accepted: 04 December 2021. Published online: 16 December 2021.
Authors:
Chau T. Tao, Department of Coastal Aquaculture, College of Aquaculture and Fisheries, Cantho University, Campus II, 3/2 Street, Nink Kieu District, Can Tho City, Viet Nam, e-mail: cttao@ctu.edu.vn
Tran N. D. Khoa, Department of Coastal Aquaculture, College of Aquaculture and Fisheries, Cantho University, Campus II, 3/2 Street, Nink Kieu District, Can Tho City, Viet Nam, e-mail: tndkhoa@ctu.edu.vn
P. M. Truyen, Department of Coastal Aquaculture, College of Aquaculture and Fisheries, Cantho University, Campus II, 3/2 Street, Nink Kieu District, Can Tho City, Viet Nam, e-mail: phamminhtruyen1970@gmail.com
Nguyen Van Hoa, Department of Coastal Aquaculture, College of Aquaculture and Fisheries, Cantho University, Campus II, 3/2 Street, Nink Kieu District, Can Tho City, Viet Nam, e-mail: nvhoa@ctu.edu.vn
Cao M. An, Department of Coastal Aquaculture, College of Aquaculture and Fisheries, Cantho University, Campus II, 3/2 Street, Nink Kieu District, Can Tho City, Viet Nam, e-mail: cma@ctu.edu.vn
Tran N. Hai, Department of Coastal Aquaculture, College of Aquaculture and Fisheries, Cantho University, Campus II, 3/2 Street, Nink Kieu District, Can Tho City, Viet Nam, e-mail: tnhai@ctu.edu.vn

How to cite this article:
Tao C. T., Khoa T. N. D., Truyen P. M., Hoa N. V., An C. M., Hai T. N., 2021 Effects of light intensity on growth and survival rate of freshwater prawn (*Macrobrachium rosenbergii*) at larvae and postlarvae stages in biofloc system. AACL Bioflux 14(6):3556-3565.