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Performance of Pacific white shrimp *Litopenaeus vannamei* raised in biofloc systems with varying levels of light exposure

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ABSTRACT

Most research on biofloc systems has been performed in greenhouses with abundant natural light. The functionality of these systems in an environment devoid of light remains poorly understood, especially with regard to growth and survival of reared animals. This study evaluated the performance of *Litopenaeus vannamei* reared in a biofloc system with varying levels of light. Treatments were 24 h with light (24WL), 12 h with light/12 h without light (12WL/12WOL), and 24 h without light (24WOL), each with four replicate tanks. The 24WL and 12WL/12WOL treatments were supplied with light intensity of 10 000 lx. Shrimp with mean ± SD initial weight of 3.3 ± 0.1 g were reared in 850 L-tanks at a density of 300 shrimp m^{-3}. With the exception of nitrate, TSS, VSS and chlorophyll *a*, there were no significant differences ($P > 0.05$) in water quality parameters among treatments. Nitrate was higher ($P < 0.05$) in 24WOL treatment than in 24WL but neither was significantly different from 12WL/12WOL. TSS and VSS were higher ($P < 0.05$) in 24WL treatment than 24WOL, but were not significantly different from 12WL/12WOL treatment. Chlorophyll *a* was higher ($P < 0.05$) in 24WL treatment than in 12WL/12WOL and 24WOL treatments. There were no significant differences ($P > 0.05$) in shrimp survival and feed conversion ratios among the treatments. However, shrimp in 24WL treatment grew at a significantly greater rate and reached a significantly greater final weight than shrimp in 24WOL treatment ($P < 0.05$), but neither was significantly different from 12WL/12WOL. The results demonstrate that shrimp production was higher in the treatment that were exposed to light; however Pacific white shrimp can be raised in total absence of light with acceptable performance.

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1. Introduction

Increasing concerns in recent years about the environmental impact of marine shrimp farms, associated with the incidence of diseases, has led to the development of production systems with little or no water exchange (Hopkins et al., 1995). Biofloc technology is a new concept in aquaculture, where manipulation of the microbial community is carried out under controlled conditions within the culture system with the raised animals (De Schryver et al., 2008). This system facilitates the production of aquatic animals at high stocking densities in a sustainable and bio-secure fashion (McAbee et al., 2003; McNeil, 2000; Vinatea et al., 2009). In some cases the protein content of feed can be reduced due to partial protein supplementation by the microbial community (Burford et al., 2004; Wasielesky et al., 2006). One of the advantages of operating a bacterial-driven system versus a conventional phytoplankton-dominated pond is that microbial production is limited by the availability of organic matter or substrate rather than light, giving rise to the potential for this system in indoor conditions (Azim et al., 2008).

Although this relatively new aquaculture technology is still developing, important research efforts have been realized to understand its operation and potential benefits (Azim and Little, 2008; Cohen et al., 2005; De Schryver et al., 2008; Wasielesky et al., 2006). The majority of research on biofloc systems has been carried out in greenhouses in tropical or subtropical regions with an abundance of natural light (Neal et al., 2010). However, little is known about the functionality of these systems in an environment without light, especially in regard to performance of farmed shrimp.

Systems operating in the absence of light may require more oxygen input during daylight hours, but the risks associated with harmful algae are reduced. By eliminating the dependence on sunlight, these systems can be housed in the controlled environment of insulated buildings, leading to a reduction in energy costs during the cold months (Ray et al., 2009).

In the presence of light algae can provide supplementary food for shrimp, nutrients for the growth of bacteria, and a basic food source for zooplankton, which can also provide supplemental nutrition for

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shrimp (Ju et al., 2008a). Additionally, in systems operated with light, oxygen supply can be reduced during the daylight hours, as a result of greater photosynthetic production, especially when the phytoplankton community composition is dominated by chlorophytes which are better oxygenators of the water compared to bloom-forming cyanobacteria and due to the faster growth rates of most eukaryotic types of phytoplankton (Ray et al., 2009; Schrader et al., 2011).

The purpose of this study was to evaluate the performance of *L. vannamei* raised in biofloc systems with varying levels of light exposure.

2. Materials and methods

2.1. Shrimp source and nursery

The study was carried out at the Laboratório de Camarões Marinhos (LCM), Estação de Maricultura da Barra da Lagoa, in Florianópolis, Santa Catarina, Brazil. PL10 *L. vannamei* were obtained in November 2010 from a commercial hatchery (Aquatec, Barra do Cunhaú, Canguaretama, RN, Brazil).

The water used was pumped from Barra da Lagoa Beach filtered through a 125 μm geotextile bag. Before starting the experiment, a round 50 000 L (50 tons) circular matrix tank was used as a nursery. The tank was inoculated with diatoms (*Thalassiosira weissflogii* and *Chaetoceros muelleri*, $\sim 3 \times 10^4$ cells mL^{-1}) to help maintain water quality until a heterotrophic community was established. Dried molasses were added daily after the addition of the feed to maintain a C:N ratio above 12:1 and control ammonia–nitrogen build-up (Avnimelech, 1999).

Shrimp were stocked into the matrix tank at a density of 390 m^{-3} to begin a nursery phase. During this phase, shrimp were fed a 40% protein shrimp diet (Guabi, Campinas, São Paulo, Brazil) at 08:00, 10:00, 13:00, and 16:00 h according to a feed chart based on shrimp biomass from samples and estimated survival. During the nursery phase, total ammonia nitrogen (TAN) and nitrite–nitrogen (NO_2–N) concentrations were monitored according to the methods described in Table 1. Shrimp were cultured in the nursery tank for 60 days and then stocked into the experimental tanks.

Table 1
Water quality parameters determined during the experiment and methods used for the analyses.

Parameters	Method
Temperature (°C)[a]	YSI 30 (Yellow Springs, OH, USA)
Dissolved oxygen (mg L^{-1})[a]	YSI 5100 (Yellow Springs, OH, USA)
pH[b]	YSI 100 (Yellow Springs, OH, USA)
Turbidity (NTU)[c]	ALFAKIT turbidity meter
Salinity (‰)[d]	YSI 30 (Yellow Springs, OH, USA)
Alkalinity (mg $CaCO_3$ L^{-1})[e]	APHA (1995) – 2320 B
Ammonia (mg TAN L^{-1})[d]	Koroleff (1969) in Grasshoff et al. (1983)
Nitrite nitrogen (mg NO_2-N L^{-1})[e]	Bendschneider and Robison (1952) in Baumgarten et al. (1996)
Nitrate nitrogen (mg NO_3-N L^{-1})[e]	HACH method 8039 (Cadmium Reduction)
Orthophosphate (mg PO_4 L^{-1})[e]	Aminot and Chaussepied (1983) in Baumgarten et al. (1996)
Total suspend solids: TSS (mg L^{-1})[d]	APHA (1995) – 2540 D
Volatile suspended solids: VSS (mg L^{-1})[d]	APHA (1995) – 2540 E
Chlorophyll *a* (mg L^{-1})[e]	APHA (1995) – 10,200 H

[a] Twice a day.
[b] Once a day.
[c] Three times a week.
[d] Twice a week.
[e] Weekly.

2.2. Experimental design

The experimental units consisted of twelve 850 L circular fiberglass tanks (bottom surface: 1.0 m^2). Central aeration (aero-tube™) was provided to maintain the solids in suspension and to ensure dissolved oxygen remained in saturation level. The tanks were kept in an isolated room and received only artificial lighting. The treatements were: 24 h of light (24WL), 12 h with light/12 h without light (12WL/12WOL) and 24 h without light (24WOL) each with four replicates. A single lamp (metal halide lamp, 400 W) was hung above the 24WL and the 12WL/12WOL treatment tanks as an artificial light source. A light intensity of 10 000 lx (ICEL LD - 550 lx meter) measured in water surface was maintained constant during the study. In the 24WOL treatment no light was provided except a flashlight during routine maintenance and sampling operations, for usually less than 30 min/day. Each experimental unit was filled with process water, and was stocked with juvenile Pacific white shrimp with mean ± SD initial weight of 3.3 ± 0.1 g for a final stocking density of 300 m^{-3}.

The trial was carried out for a period of 40 days between February and March 2011.

2.3. Water quality management

The water quality parameters, their monitoring frequencies and methodology of analysis are shown in Table 1. The water temperature of each tank was controlled by thermostats (29.0–30.0 °C) and maintained by 1000 W heaters. When the alkalinity dropped below 120 mg L^{-1}, hydrated lime was applied at the rate of 15% of daily feed input. For each tank, whenever TAN concentration exceeded 1 mg L^{-1}, dried molasses (69% of carbohydrate) was applied using 20 g of carbohydrates per gram of total ammonia nitrogen, considering that approximately 40% of nitrogen supplied as feed to the shrimp was transformed into ammonia (Avnimelech, 1999).

The levels of total suspended solids (TSS) were maintained between 400 and 600 mg L^{-1} through its periodic removal by using 0.12 m^2 cylindrical settling chambers. The settlers were operated during 7 h at the time that TSS levels exceeded 600 mg L^{-1}, using an overflow rate between 0.44 and 0.60 m^3 m^{-2} h. The TSS removal efficiencies were considered to be around 70–55%, respectively. The frequency of use was considering approximately 25% of TSS production over the total amount of feed added to each tank (Ebeling et al., 2006).

All units were operated with zero water exchange; however, water was added as needed to replace evaporative losses and sludge removal (approximately 5%).

2.4. Shrimp production

During the trial shrimp were fed three times per day (09:00, 13:00 and 18:00 h) with 35% crude protein (CP) commercial diet (Potimar 35 EXT, Guabi, Campinas, São Paulo, Brazil), through feeding trays at an initial rate of 10% of the biomass in each tank with adjustments according to apparent consumption.

Weight gain was monitored weekly by weighing individually 20 shrimp using a digital scale (100 ± 0.01 g). The final weight, survival and biomass were recorded at the end of the trial by counting and weighing the surviving shrimp. The feed conversion ratio (FCR) was estimated as the total wet weight gain/total weight of feed supplied.

2.5. Statistical analyses

Growth performance data were analyzed using one-way ANOVA. The survival data were transformed to arcsine prior to the analysis but only original values are presented. The water quality variables data were compared by two-way repeated measures

Table 2
Mean ± SD (range) of water quality parameters after 40 days of growth of *L. vannamei* in 24 h with light (24WL), 12 h with light/12 h without light (12WL/12WOL) and 24 h without light (24WOL).

Parameter	Treatment		
	24WL	12WL/12WOL	24WOL
Temperature (°C)			
AM	30.4 ± 0.5 (28.8–31.9)	30.2 ± 0.5 (28.0–31.6)	30.2 ± 0.5 (28.7–31.6)
PM	30.4 ± 0.5 (29.5–31.8)	30.4 ± 0.4 (29.0–31.4)	30.2 ± 0.5 (28.3–31.6)
Oxygen (mg L^{-1})			
AM	5.5 ± 0.9 (4.1– 6.5)	5.5 ± 0.7 (4.3–6.5)	5.5 ± 0.5 (4.4–6.5)
PM	5.3 ± 0.9 (4.0–6.5)	5.3 ± 0.7 (3.8–6.4)	5.4 ± 0.5 (4.4–6.4)
pH	7.9 ± 0.1 (7.6–8.3)	7.8 ± 0.1 (7.0–8.3)	7.8 ± 0.1 (7.5–8.1)
Salinity (‰)	32.6 ± 0.8 (29.9–34.6)	32.7 ± 0.7 (31.3–34.3)	32.8 ± 0.6 (31.4–34.3)

Table 3
Mean ± SD (range) of water quality parameters after 40 days of growth of *L. vannamei* in 24 h with light (24WL), 12 h with light/12 h without light (12WL/12WOL), and 24 h without light (24WOL). Means within a row followed by different superscript letters were significantly different ($P < 0.05$).

Parameter	Treatment		
	24WL	12WL/12WOL	24WOL
TAN (mg TAN L^{-1})	0.3 ± 0.1 (0.2–0.5)	0.3 ± 0.1 (0.1–0.9)	0.3 ± 0.1 (0.2–0.4)
NO_2–N (mg NO_2–N L^{-1})	0.3 ± 0.1 (0.2–0.8)	0.3 ± 0.1 (0.2–0.6)	0.3 ± 0.1 (0.2–0.4)
NO_3–N (mg NO_3–N L^{-1})	11.9 ± 5.7^{a} (0.6–28.5)	15.6 ± 5.4^{ab} (7.0–31.4)	18.1 ± 8.4^{b} (6.1–33.4)
PO_4 (mg PO_4 L^{-1})	0.7 ± 0.3 (0.3–1.4)	0.9 ± 0.4 (0.3–1.7)	0.9 ± 0.2 (0.4 –1.4)
Alkalinity (mg $CaCO_3$ L^{-1})	178.2 ± 34.1 (120.0–242.0)	167.1 ± 29.5 (112.0–230.0)	159.6 ± 26.4 (110.0–208.0)
Turbidity (NTU)	197.5 ± 79.2 (42.5–433.7)	189.1 ± 83.2 (26.9–407.6)	187.8 ± 75.0 (37.9–399.7)
TSS (mg L^{-1})	607.3 ± 67.5^{a} (352.0–741.0)	591.1 ± 74.9^{ab} (336.0–791.0)	579.5 ± 66.5^{b} (352.0–763.0)
VSS (mg L^{-1})	273.7 ± 47.8^{a} (190.0–371.0)	265.1 ± 48.4^{ab} (169.0–376.0)	258.4 ± 45.7^{b} (176.0–374.0)
Chl *a* (mg L^{-1})	0.17 ± 0.12^{a} (0.37–0.08)	0.07 ± 0.06^{b} (0.14–0.01)	0.05 ± 0.05^{b} (0.12–0.01)

ANOVA with treatment as the main factor and sampling data as repeated measures factor. If significant differences were found, Tukey's multi-comparison test was applied at a 5% significance level. Statistical analysis were carried using the STATISTICA Version 8 (StatSoft South America, Brazil), and the results are presented as means ± SD (standard deviation).

3. Results

3.1. Water quality

There were no significant differences ($P > 0.05$) among treatments in terms of water temperature, dissolved oxygen, pH and salinity (Table 2). Overall mean (±SD) were morning water temperature (30.3 ± 0.5 °C); afternoon water temperature (30.3 ± 0.5 °C); morning dissolved oxygen (5.5 ± 0.7 mg L^{-1}); afternoon dissolved oxygen (5.5 ± 0.7 mg L^{-1}); pH (7.8 ± 0.1); and salinity (32.6 ± 0.7‰).

With the exception of nitrate, there were no significant differences ($P > 0.05$) in the concentrations of ammonia, nitrite and phosphate among treatments. Concentrations of nitrate were significantly higher ($P < 0.05$) in the 24WOL treatment (18.1 ± 8.4 mg L^{-1}) as compared to the 24WL (11.9 ± 5.7 mg L^{-1}), but was not significantly different ($P > 0.05$) from the 12WL/12WOL treatment (15.6 ± 5.4 mg L^{-1}). The concentrations of TSS and VSS were significantly higher ($P < 0.05$) in the 24WL treatment (607.3 ± 67.5 and 273.7 ± 47.8 mg L^{-1}, respectively) as compared to the 24WOL treatment (579.5 ± 66.5 and 258.4 ± 45.7 mg L^{-1}). However, neither the 24WL nor the 24WOL were significantly different to the 12WL/12WOL treatment (591.1 ± 74.9 and 265.1 ± 48.4 mg L^{-1}) (Table 3).

Variations in concentrations of chlorophyll *a* (Chl *a*) are shown in Fig. 1. Chl *a* concentrations were significantly higher ($P < 0.05$) in the 24WL treatment during the entire trial and there was no significant difference ($P > 0.05$) between the other two treatments. Chl *a* concentrations decreased over time in the 12WL/12WOL and the 24WOL treatments, whereas in the 24WL this pigment had a slight increase from day 21 until the end of the study.

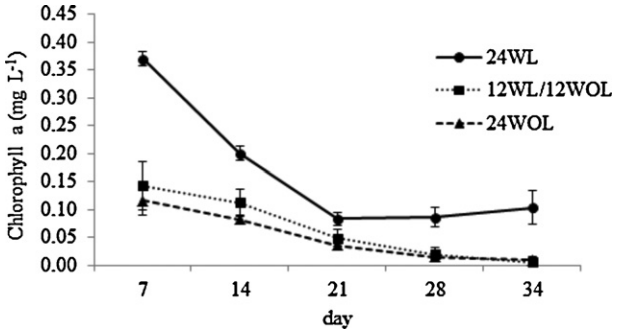

Fig. 1. Concentrations of chlorophyll-a (mg L^{-1}) during the grow-out of *L. vannamei* in 24 h with light (24WL), 12 h with light/12 h without light (12WL/12WOL), and 24 h without light (24WOL). Error bars represent one standard deviation around the mean.

3.2. Shrimp production

After 40 days, significant differences ($P < 0.05$) were found in the mean final weight, the weight gain and the shrimp biomass among treatments (Table 4). These parameters were significantly higher ($P < 0.05$) in the 24WL treatment compared to the 24WOL. However, neither the 24WL nor the 24WOL was significantly

Table 4
Mean ± SD (range) of final weight, weight gain, FCR, survival and biomass of *L. vannamei* after 40 days of growth in 24 h with light (24WL), 12 h with light/12 h without light (12WL/12WOL), and 24 h without light (24WOL). Means within a row followed by different superscript letters were significantly different ($P < 0.05$).

Parameter	Treatment		
	24WL	12WL/12WOL	24WOL
Final weight (g)	10.4 ± 0.3^{a}	9.7 ± 0.7^{ab}	9.1 ± 0.3^{b}
Weight gain (g $week^{-1}$)	1.2 ± 0.1^{a}	1.1 ± 0.1^{ab}	1.0 ± 0.1^{b}
FCR	1.9 ± 0.1	2.6 ± 0.8	2.2 ± 0.2
Survival (%)	97.4 ± 1.9	86.8 ± 10.5	86.8 ± 5.96
Biomass (kg m^{-2})	2.7 ± 0.1^{a}	2.3 ± 0.4^{ab}	2.1 ± 0.2^{b}

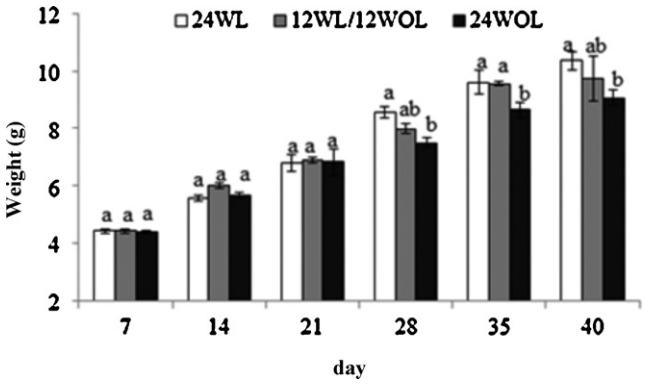

Fig. 2. Mean weight during the 40 days grow-out of *L. vannamei* in 24 h with light (24WL), 12 h with light/12 h without light (12WL/12WOL), and 24 h without light (24WOL). Error bars represent standard deviation around the mean, while a or b indicate significant differences ($P < 0.05$).

different ($P > 0.05$) from the 12WL/12WOL. There were no significant differences ($P > 0.05$) in survival and FCR among the treatments. There were no significant difference ($P > 0.05$) among treatments in both weight gain and feed intake during the first 21 days of the study. By day 28, the 24WL treatment had a significantly higher ($P < 0.05$) mean weight gain as compared to the 24WOL treatment and continued high until harvest (Figs. 2 and 3).

4. Discussion

4.1. Water quality

All the water quality parameters remained within the ranges reported as suitable for the culture of Pacific white shrimp (Van Wyk and Scarpa, 1999; Wickins, 1976).

The concentrations of TAN and nitrite recorded throughout the trial were maintained in adequate levels recommended for juveniles of Pacific white shrimp (Lin and Chen, 2001, 2003). The low concentrations of nitrite observed during the culture period suggest the complete oxidation of ammonia to nitrate (Cohen et al., 2005). Studies evaluating water quality in zero-exchange systems report low concentrations of ammonia and nitrite (Burford et al., 2004; McIntosh et al., 2000; Ray et al., 2010; Vinatea et al., 2010; Wasielesky et al., 2006), resulting from the removal of these compounds by microbial community (Ebeling et al., 2006).

Nitrate concentration in the 24WL treatment was low, due to the lower concentration of ammonia nitrogen available to the oxidation by nitrifying bacteria (Holl et al., 2011). The absorption of this reduced form of inorganic nitrogen by phytoplankton was probably the primary cause, since the Chl *a* concentrations in this treatment was higher than the others treatments. The ammonia nitrogen was found as the preferred source of inorganic nitrogen for phytoplankton in intensive biofloc shrimp culture systems as evidenced by Holl et al. (2011).

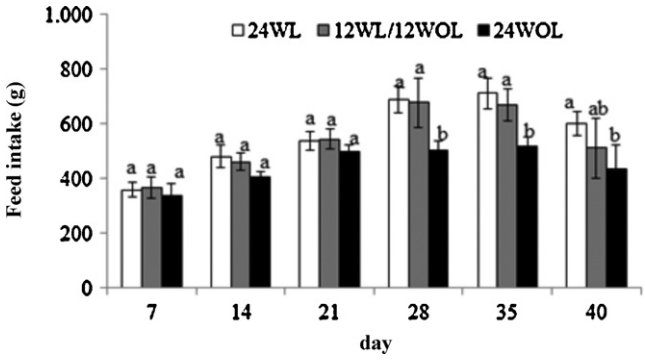

Fig. 3. Amount of feed added in the experimental units during the 40 days grow-out of *L. vannamei* in 24 h with light (24WL), 12 h with light/12 h without light (12WL/12WOL), and 24 h without light (24WOL). Error bars represent standard deviation around the mean, while a or b indicate significant ($P < 0.05$).

Chl *a* concetrations were influenced by light. The decreases in the concentrations of Chl *a* verified during the study are probably associated with the use of molasses to control ammonia in the first 18 days. The use of carbon sources in intensive systems promotes succession and dominance of bacteria over microalgae (González-Félix et al., 2007; Ju et al., 2008a). Chl *a* concetrations in the present study were lower than those reported by Burford et al. (2003, 2004), Decamp et al. (2007) and Martinez-Cordonova et al. (2002) for white shrimp production in zero-water exchange systems.

4.2. Shrimp production

The results of this study suggest that the presence of light in shrimp production may influence their performance. The increase in microalgae concentration (Godoy et al., 2012), and animal behavioral changes associated with the presence of light may help explain these differences.

It has been suggested that natural productivity in zero-exchange shrimp production systems provide supplemental food resources, reducing feed costs and improving shrimp growth rate (Otoshi et al., 2011; Wasielesky et al., 2006). The ability of Pacific white shrimp to utilize natural productivity and its effect for enhancing shrimp growth is well documented (Burford et al., 2004; Decamp et al., 2003; Otoshi et al., 2011, 2001; Wasielesky et al., 2006). Ju et al. (2009) suggest that microalgae in the microbial floc may play a key role in improving shrimp growth rates. The highest growth rate observed in the 24WL treatment can be associated with Chl *a*, suggesting greater phytoplankton biomass acting as a source of essential fatty acids (PUFAs, DHA, and EPA), essential amino acids, vitamins, and carotenoids for shrimps. This result is similar to those reported by Divakaran and Moss (2004), who observed a higher growth of shrimp in ponds with a higher concentration of Chl *a*. Ju et al. (2008b) attributed the highest growth rates obtained by shrimp fed diets with inclusion of whole floc to the presence of bioactive compounds including chlorophylls. Becker (1994) and Olvera-Novoa et al. (1998) reported that all microalgae biomass are rich in polyunsaturated fatty acids and can be an important source of essential fatty acids for aquatic animals.

The shrimp production is 22% higher in the 24WL treatment compared to the 24WOL treatment which indicates the positive influence of light. Similar patterns were observed by Neal et al. (2010) who obtained shrimp production 48% greater in ponds with natural light in relation to low light, reporting a positive impact of light on the availability of rotifers and other zooplankton species, which are natural food sources for shrimp. Ray et al. (2009) also reported shrimp production 17% higher and FCR 18% lower in a photoautotrophic raceway, compared to a totally heterotrophic raceway, and suggested that photoautotrophic organisms may have provided supplementary feed for the shrimp.

The reduction of swimming activity in the presence of light is well documented (Hoang et al., 2003; Pontes, 2006; Pontes and Arruda, 2005; Wang et al., 2003; Zhang et al., 2006), and these authors agree that this reduction means more energy for somatic growth and less energy in respiration and excretion. However, neither swimming activity of shrimp nor their physiological condition were evaluated in this study.

Some studies on fish showed a positive correlation between the presence of light and the increase in feed intake (Boeuf and Le Bail, 1999; Fielder et al., 2002). However, contrary to what occurs in fish, light is not necessary for shrimp to locate food, because they use

chemoreceptors as the main way (You et al., 2006). The differences verified in mean weight among the treatments only after day 28 show that the light did not influence the amount of feed eaten by shrimp during total rearing period, these differences are a result of other factors such as available of natural production actings as an additional feed soure (Decamp et al., 2002; Moss, 2002; Godoy et al., 2012).

Although light has promoted differences in shrimp growth, survival was not affected. Other studies have already shown that light does not affect the survival: *Macrobrachium amazonicum* (Araujo and Valenti, 2011), *Penaeus merguiensis* (Hoang et al., 2003), *Litopenaeus vannamei* (Neal et al., 2010; You et al., 2006) and *Fenneropenaeus chinensis* (Wang et al., 2004). Survival of Pacific white shrimp observed in this study was within the range of super-intensive studies reported by Decamp et al. (2007), McAbee et al. (2003), McIntosh et al. (2000), Neal et al. (2010) and Samocha et al. (2007), suggesting that Pacific white shrimp can be raised in biofloc systems with varying levels of light exposure without compromising survival rates.

Feed conversion rate is an important parameter in aquaculture because feed costs generally represent up to 60% of the total production cost (Cuzon et al., 2004; Tacon et al., 2002). The FCRs obtained in this study were not affected by different illumination conditions and were similar to those obtained by McIntosh et al. (2000), Neal et al. (2010) and Samocha et al. (2007), and lower than those obtained by Ju et al. (2008b).

Weight gain of shrimp raised without light was higher than that obtained by Esparza-Leal et al. (2010) and Ray et al. (2010) and similar to that obtained by Ju et al. (2008b) and Neal et al. (2010), suggesting the growth feasibility of Pacific white shrimp without light, eliminating photoautotrophic organisms.

Systems operated without light reduce the risks associated with harmful algae, which can proliferate during shrimp production (Ray et al., 2009). These harmful algae have several undesirable attributes including poor base for aquatic food chains; the propensity to form blooms which can lead to large shifts in dissolved oxygen levels due to the rapid formation and die-offs of the cyanobacterial blooms; and some species of cyanobacteria produce toxins and impart unpleasant flavors to cultured animals which can negatively affect shrimp quality (Alonso-Rodríguez and Paez-Osuna, 2003; Ju et al., 2008a; Ray et al., 2009; Schrader et al., 2011).

5. Conclusion

This study demonstrates that shrimp production was significantly higher in the treatment that were exposed to light; however Pacific white shrimp can be raised in total absence of light with acceptable performance. Our results suggest the importance of the presence of light in culture medium. Factors such as energy, operational expenses, and production goals must be considered.

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