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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.

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