BOLETIM DO INSTITUTO DE PESCA
ISSN 1678-2305 online version
Scientific Article

Production of Pacific white shrimp in biofloc system with different food management strategies

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Received: December 12, 2022
Approved: December 5, 2022

ABSTRACT

In the present work, different models for adjustments in feeding rates to produce Pacific white shrimp (*Litopenaeus vannamei*) in a biofloc system were analyzed. Shrimps were stocked with an initial weight of 4.21 ± 0.09 g at a density of 250 shrimp m^{-3} and fed following different methodologies for 60 days. The first method was according to the Van-Wyk table, considering the minimum (MIN) and maximum (MAX) feed rates. The second was according to two estimated values from the feed conversion ratio (FCR; FCR of 1.1 and 1.5), based on the methodology determined by Garzade Yta. A completely randomized experimental design was adopted, consisting of four treatments (MAX, MIN, FCR 1.1, and FCR 1.5) with 4 independent replicates. Zootechnical performance, the physical and chemical water quality parameters, and the production of solids in the system were evaluated. The treatment that used minimum amounts of feed determined by the table showed a better feed conversion, survival, using a lower amount of feed and, thus, generating less waste. Although the feeding strategy using the minimum values in the table has shown better results, it is still necessary to improve these strategies, as the biofloc system is a system that has variations and their adjustments must be made according to the interactions of the system.

Keywords: *Litopenaeus vannamei*; feed; feeding tables.

Produção do camarão-branco-do-pacífico em sistema de bioflocos com diferentes estratégias de manejo alimentar

RESUMO

No presente trabalho foram analisadas diferentes modelos para ajustes nas taxas de alimentação para a produção do camarão camarão-branco-do-pacífico (*Litopenaeus vannamei*) em sistema de bioflocos. Os camarões foram povoados com peso inicial de 4,21 ± 0,09 g na densidade de 250 camarões m^{-3}, e alimentados seguindo as diferentes metodologias durante 60 dias. A primeira seguiu a tabela de Van-Wyk, considerando as taxas mínimas (MIN) e máximas (MAX) de ração. A segunda foi de acordo com dois valores estimados do cálculo de conversão alimentar (FCR de 1.1 e 1.5), baseado na metodologia determinada por Garzade Yta et al. (2004). Foi adotado um delineamento experimental inteiramente casualizado, composto por quatro tratamentos (MIN, MAX, FCR 1.1 e FCR 1.5) com 4 repetições cada. Foram avaliados o desempenho zootécnico, os parâmetros físicos e químicos da água e a produção de sólidos do sistema. O tratamento que utilizava quantidades mínimas de ração determinada pela tabela apresentou uma melhor conversão alimentar, sobrevivência, utilizando uma menor quantidade de ração e gerando uma menor quantidade de resíduos. Embora a estratégia de alimentação utilizando os valores mínimos da tabela tenha apresentado melhores resultados, ainda é necessário o aprimoramento dessas estratégias, pois o sistema de bioflocos possui variações e seus ajustes devem ser feitos de acordo com as interações do sistema.

Palavras-chave: *Litopenaeus vannamei*; ração; tabelas de alimentação.

INTRODUCTION

The aim of aquaculture intensification is to maximize feed efficiency while taking care of the health of the production system and the specific environment (Nunes and Parsons, 2006). biofloc technology (BFT) has been considered an important alternative to assist in the development of shrimp production (Crab et al., 2010). The maintenance of water quality is one of the important contributions of the biofloc in shrimp farming, enabling a biosafe system and available to the demand for water (Ray et al., 2010). It also observes the nutritional contribution of the biofloc for shrimp, and then, the need for artificial foods (Wasielesky Jr. et al., 2006; Emerenciano et al., 2013).

The biofloc present in the water can help to reduce cost with artificial feeding by supplementing food with the flocs produced in the system (Avnimelech, 2007; Samocha et al., 2007), which can reach 40 to 60% of the total cost of production in intensive systems (Quintero and Roy, 2010; Rego et al., 2017). Thus, good feed management is the foundation for the success and sustainability of the aquaculture industry and drives the search for new strategies to increase production profits. (Sedgwick, 1979; Velasco et al., 1999; Araujo and Valenti, 2005).

One of the difficulties in shrimp production is monitoring food consumption, making feed management a necessary practice in the production process (Carvalho and Nunes, 2006). Despite this difficulty, research has been conducted focusing on improving feeding techniques in shrimp production.

Although nutritional knowledge has improved considerably, enabling producers to provide high-quality feed, the potential for significant performance improvement can only be fully expressed if proper feeding strategies are practiced (Davis and Venero, 2005). Well-managed feeding programs will provide adequate feed to meet the nutritional demands and feeding habits of farm animals at different stages of development, ensuring that nutrients from artificial feed and natural foods are used efficiently. Despite its importance, there is still not abundant literature on feeding strategies for shrimp in biofloc systems.

Regarding strategies, the customization of feeding tables serves as an additional source of information for production managers and shrimp farm managers to identify possible deviations in feeding or problems in the cultivated population. In addition, it has the potential for more accurate and rigorous monitoring of feeds, allowing the observed results to be constantly aligned with pre-established production goals (Martinez-Cordova et al., 1998; Casillas-Hernández et al., 2007).

Many producers still use conventional tables as a basis for the supply of food, where they consider the size and biomass of organisms to adjust in the amounts of feed daily offered. Another feed management methodology is the use of feeding trays, where adjustment is made according to apparent feed intake (Martinez-Cordova et al., 1998; Smith et al., 2002; Casillas-Hernández et al., 2007). Therefore, some studies suggest that it is necessary to consider the actual consumption and assimilation of the feed for a better strategy, taking into account the environmental conditions.

Another way to offer feed is through programmed feed conversion. In it is possible to have the amount of feed to be offered by the growth estimate and the programmed conversion.

Feed manufacturers follow the trend of formulating feed for each type of system and have made available a specially formulated feed for use in super-intensive systems dominated by bioflocs. This food is more expensive than what is available on the market for intensive shrimp production systems, for example, those formulated for semi-intensive systems. However, this tendency to use foods specially formulated for each type of system has been little investigated, requiring further studies that allow the use of adequate food for each system at a viable cost (Braga et al., 2016).

Thus, it is necessary to adjust feeding tables for superintensive systems, especially those dominated by bioflocs. These tables must consider the food supplementation of the flocs for the shrimp, contributing to the reduction of food supply and helping to maintain good levels of water quality, with a reduction in the generation of solids in the breeding environment. In this sense, this study aimed to investigate the zootechnical performance of *L. vannamei* and the water quality of the crop using different feeding strategies in biofloc systems.

MATERIAL AND METHODS

The experiment was conducted at the Laboratory of Marine Shrimp – LCM, Universidade Federal de Santa Catarina – UFSC, located in Barra da Lagoon, Florianópolis, Santa Catarina (27.57° S, 48.4° W) for 60 days in the year 2020.

Biological material

Shrimp *Litopenaeus vannamei* were purchased from the commercial laboratory Aquatec Ltda., RN. The animals were stored in a BFT nursery until they reached approximately 4.21 ± 0.09 g, when they were then transferred to the experimental units.

Experimental unit and design

The shrimp were distributed in 16 tanks of 800 L of useful volume, at a density of 250 shrimp m^{-3}. Each unit had a central ring with Aerotubes® micro-perforated hoses in order to provide agitation and oxygenation (≥ 5 mg L^{-1}) of the water column and prevent solids sedimentation. The temperature (29.58 ± 0.04°C) was maintained with submerged electric heaters (800 W). The tanks were covered with a net, installed in a greenhouse with natural photoperiod. An artificial substrate (polyester fiber) of the Needlona® type was used, consisting of four rectangular plates (0.40 × 0.55 m), representing 80 % of the surface area of the tank.

The water of the experimental units was prepared with 30 % of inoculum from shrimp farming tanks in a mature biofloc system and the remaining volume was completed with seawater (34 g L^{-1} of salinity), starting the cultivation with 300 mg L^{-1} of total suspended solids.

To determine the amount of feed offered, two calculation strategies were used, adopting a completely randomized experimental design consisting of four treatments and four replications each: For the MAX and MIN treatments, the Van-Wyk feeding table was used (Table 1), where the minimum and maximum feed rates for the average weight of shrimp for the MIN and MAX treatments, respectively, were considered.

The second strategy followed the calculation described by Garzade Yta et al. (2004), with two different programmed feed conversion values, based on Equation 1 described below:

AF= (N*G*FCR*S) / 7 (1)

Where:
AF = amount of daily feed;
N = number of shrimps stored;
G = expected weekly growth (g week^{-1});
FCR = Expected food conversion for the week;
S = expected survival (%) for the week.

Thus, FCR of 1.1 and 1.5 were previously estimated.

Shrimps were fed a commercial feed of 1.6 mm with 35 % crude protein (Guabi Poti Guaçu 1.66 mm) supplied four times a day (8:30, 11:30, 14:30, and 17:30 h) adjusted weekly after the biometrics according to the methodology proposed in each treatment.

Water quality parameters

During the experiment, dissolved oxygen and temperature were monitored twice a day using the YSI pro20 oximeter. Twice a week, salinity was checked with a refractometer, pH (pHmeter Thermo Scientific Orion Star A211), alkalinity (titrametric method) (APHA, 2005 — 2320B) and, total suspended solids (TSS) (APHA, 2005 — 2540D) through the Imhoff cone were also determined. When the pH and alkalinity below 7.3 and 150 mg L^{-1}, respectively, were corrected with the addition of calcium hydroxide (Furtado et al., 2011). TSS was kept between 400 and 600 mg L^{-1}, adequate levels for *L. vannamei*, and the excess was removed using a decanter, as suggested by Schveitzer et al. (2013).

The total ammonia nitrogen (TAN) was measured following the methodology of (Grasshoff et al., 1983) and nitrite (N-NO_2) according to Strickland and Parsons (1972) twice a week.

Table 1. Feeding table for intensive shrimp cultivation according to Van Wyk and Scarpa (1999).

Final mean weight (g)	Feed rate (% biomass day^{-1})
3.0–3.9	8–7
4.0–4.9	7–6
5.0–5.9	6–5.5
6.0–6.9	5.5–5.0
7.0–7.9	5.0–4.5
8.0–8.9	4.5–4.25
9.0–9.9	4.25–4.0
10.0–10.9	4.0–3.75
11.0–11.9	3.75–3.5
12.0–12.9	3.5–3.0
13.0–13.9	3.0–2.75
14.0–14.9	2.75–2.5
15.0–15.9	2.5–2.3

Nitrate (N-NO_3) and Phosphate (PO_4) were measured at the beginning, middle and end of the experiment by the Kit Hach NitraVer 5 (nitrate reagent powder pillows) and ascorbic acid method (APHA, 2017), respectively.

Zootechnical performance

To assess the performance of the animals, weekly biometrics were performed with 30 animals, using a digital scale with a precision of 0.01 g. The following were measured: average shrimp weight (g), survival (%), specific growth rate (TCE), apparent feed conversion ratio (AFCR), biomass (kg), yield (kg m^{-3}), and condition factor (K).

Statistical analysis

The data were subjected to normality (Shapiro-Wilk) and homoscedasticity (Levene) tests, with proof of these assumptions, a one-way ANOVA was used, followed by Tukey's test, when necessary, to verify the differences between treatments. The significance level adopted was 5% in all analyses. All analyses were performed using STATISTICA® version 7.0 software.

RESULTS

The results obtained for the parameters of ammonia, nitrite, nitrate, and phosphate did not show significant differences ($p \geq 0.05$) between the different treatments. The alkalinity showed a significant difference so that the two treatments using the table (MIN and MAX) and the two using programmed feed conversion (FCR 1.1 and FCR 1.5) were equal to each other, and being different between the two treatments for each of the strategies to determine the feeding rate. The parameters pH and total suspended solids showed significant differences ($p < 0.05$) between the different treatments during the 60 days of the experiment, the mean values of the results obtained for these parameters are shown in Table 2.

The zootechnical performance indices of the reared shrimp showed significant differences ($p < 0.05$) in all parameters between the different treatments, the MAX and MIN treatments showed an average weight, weekly growth, and production greater than the treatments using the calculations with the scheduled conversion. Survival values in the MAX and FCR 1.1 treatments were different from each other and were similar to the FCR 1.5 treatment. The better AFCR were observed in treatments FCR 1.5 and MIN (Table 3).

DISCUSSION

The parameters of ammonia, nitrite, nitrate, and phosphate remained within the stipulated for the species *L. vannamei* throughout the experiment as reported by Lin and Chen (2001),

Table 2. Physicochemical water parameters during *L. vannamei* cultivation in biofloc systems with different feeding strategies.

Parameters	Treatments					
	MAX	MIN	FCR 1.1	FCR 1.5	CV (%)	p-value
Ammonia (mg L^{-1})	0.32 ± 0.22 (0.00 – 0.99)	0.19 ± 0.11 (0.00 – 0.66)	0.21 ± 0.13 (0.00 – 0.64)	0.23 ± 0.16 (0.00 – 0.75)	5.17	0.12
Nitrite (mg L^{-1})	0.41 ± 0.26 (0.00 – 0.85)	0.36 ± 0.25 (0.09 – 0.84)	0.32 ± 0.24 (0.01 – 0.73)	0.42 ± 0.28 (0.00 – 0.84)	113.6	0.51
Nitrate (mg L^{-1})	11.84 ± 6.97 (4.78 – 23.24)	11.77 ± 7.53 (4.78 – 22.78)	10.34 ± 4.63 (4.76 – 16.96)	11.96 ± 6.67 (4.78 – 26.11)	61.76	0.76
Phosphate (mg L^{-1})	1.70 ± 0.71 (0.77 – 2.52)	1.62 ± 0.69 (0.77 – 2.50)	1.51 ± 0.56 (0.77 – 2.00)	1.71 ± 0.69 (0.77 – 2.00)	12.24	0.10
Alkalinity (mg L^{-1})	167.31 ± 30.4[a] (100 – 244)	170.55 ± 38.2[a] (100 – 320)	151.78 ± 20.74[b] (92 – 200)	153.41 ± 25.51[b] (100 – 224)	18.32	< 0.01
pH	7.91 ± 0.09[a] (7.68 – 8.22)	7.97 ± 0.09[b] (7.76 – 8.15)	8.01 ± 0.05[b] (7.75 – 8.11)	8.00 ± 0.13[b] (7.04 – 8.10)	1.29	< 0.01
TSS (mg L^{-1})	495.52 ± 88.22[a] (299 – 713)	484.98 ± 78.22[a] (316 – 641)	438.89 ± 76.06[b] (232 – 600)	462.15 ± 65.79[a] (280 – 582)	16.33	< 0.01

Data presented as mean ± standard deviation (minimum – maximum); Means in the same line with different letters differ from each other by the Tukey test; CV (%): coefficient of variation; MAX: Maximum feeding rate according to with the Van-Wyk table; MIN: Minimum feeding rate according to Van-Wyk table; FCR 1.1: Feed rate with feed conversion estimate estimated at 1.1; FCR 1.5: Feed rate with feed conversion estimate estimated at 1.5; TSS: total suspended solids.

Table 3. Production parameters of *L. vannamei* cultivated in biofloc systems with different feeding strategies.

Parameters	Treatments					
	MAX	MIN	FCR 1.1	FCR 1.5	CV (%)	p-value
Final mean weight (g)	15.32 ± 0.63[a] (14.69 – 15.96)	13.61 ± 1.16[a] (12.72 – 14.90)	8.94 ± 0.88[b] (8.24 – 9.93)	10.42 ± 0.36[b] (10.14 – 10.83)	7.22	< 0.01
Survival (%)	79.67 ± 9.75[b] (68.5 – 86.5)	93.17 ± 10.25[a] (83.0 – 103.5)	81.50 ± 6.73[b] (74.0 – 87.0)	88.33 ± 1.61[ab] (86.5 – 89.5)	8.60	0.04
AFCR	2.52 ± 0.43[ab] (2.18 – 3.01)	2.09 ± 0.17[b] (1.94 – 2.28)	2.83 ± 0.10[a] (2.73 – 2.93)	2.24 ± 0.07[b] (2.16 – 2.28)	13.47	< 0.01
Production (Kg m^{-3})	2.64 ± 0.85[a] (1.42 – 3.31)	3.24 ± 0.12[a] (3.09 – 3.38)	1.75 ± 0.09[c] (1.62 – 1.84)	2.29 ± 0.05[b] (2.24 – 2.34)	5.88	< 0.01
Weekly growth (cm)	1.38 ± 0.07[a] (1.31 – 1.45)	1.21 ± 0.15[a] (1.04 – 1.32)	0.57 ± 0.11[b] (0.49 – 0.69)	0.77 ± 0.04[b] (0.74 – 0.82)	11.26	< 0.01
Feed supplied (Kg)	3.92 ± 0.85[c] (3.85 – 4.02)	3.57 ± 0.95[b] (3.43 – 3.66)	1.62 ± 0.00[a] (1.62 – 1.62)	2.21 ± 0.00[a] (2.21 – 2.21)	7.22	< 0.01
Calcium hydroxide (Kg)	1.31 ± 0.16[b] (1.15 – 1.46)	1.19 ± 0.22[b] (0.85 – 1.32)	0.63 ± 0.05[a] (0.59 – 0.68)	0.85 ± 0.05[ab] (0.81 – 0.92)	4.76	< 0.01

Data presented as mean ± standard deviation (minimum – maximum); Means in the same line with different letters differ from each other by the Tukey test; CV (%): coefficient of variation; MIN: Minimum feeding rate according to Van-Wyk table; MAX: Maximum feeding rate according to Van-Wyk table; FCR 1.1: Feed rate with feed conversion estimate estimated at 1.1; FCR 1.5: Feed rate with feed conversion estimate estimated at 1.5; AFCR: apparent feed conversion ratio.

Lin and Chen (2003), Furtado et al. (2015), and Barak et al. (2003), respectively. This is probably due to the use of a mature biofloc inoculum at the beginning of the experiment, composed of nitrifying and/or heterotrophic bacteria that keep the nitrogenous compounds stable in the system (Ferreira et al., 2021).

The values of total suspended solids concentrations were significantly different, but all treatments had concentrations below 500 mg L^{-1} remaining within the species limit, as recommended (Samocha et al., 2007; Gaona et al., 2011). Whenever the concentrations of total suspended solids increased above 500 mg L^{-1}, the decanters were activated, carrying out the removal of excess solids into the system. Schveitzer et al. (2013) noted that the nitrification process is affected with total suspended solids concentrations below 200 mg L^{-1} and concentrations above 800 mg L^{-1} cause clogging of the gills and increase mortality rates.

In relation to pH and alkalinity, the treatments showed significant differences, where it was found that the highest values of alkalinity and pH were found sequentially according to the amounts of feed provided in the treatment; an explanation for this is the fact of determining the amount of calcium hydroxide supplied to regulate these parameters to be calculated according to your percentage of feed. pH levels below 7 can negatively affect shrimp performance and crop water quality, and in biofloc systems these pH levels tend to decrease, making it necessary to apply alkalinizing agents to control alkalinity and pH (Furtado et al., 2011). In minimum water exchange systems, alkalinity concentrations must remain between 100 and 150 mg $CaCO_3$ L^{-1}, where the main alkalinity reducing agents will be the nitrifying bacteria present in the biofloc (Ebeling et al., 2006).

In studies carried out in biofloc systems, survival values ranged from 68.9 to 96.2% and feed conversion from 1.1 to 2.1 (Samocha et al., 2007; Mishra et al., 2008). Our experiment showed survival rates ranging from 79.6 to 95.8% and feed conversion factors between 2.05 and 3.05, showing significant differences between treatments. These feed conversion factors are considered high according to other work carried out in biofloc systems, where microbial flocs provided feed supplementation to shrimp (Cohen et al., 2005; Ballester et al., 2007; Wasielesky et al., 2013).

The final weight of shrimp reared with different feeding strategies showed significant differences between treatments, due to the different amounts of feed provided for each treatment. It can be noted that the animals of the treatments with the maximum and minimum values of the table, which received a greater amount of feed, showed greater growth.

To make the best use of the feed adjustment calculation proposed by Garzade Yta et al. (2004), it is important to have a thorough understanding of the operation of the farming system and the factors that affect shrimp performance, such as feeding, parentage, and the effects of water quality variables. Samocha et al. (2007) used this calculation in their study in a low-density biofloc system (81 shrimp m^{-3}) and observed good feeding of the animals. However, at low stocking densities, there are occasional opportunities for feed management.

CONCLUSION

The results show that the feeding strategy with minimum feed amounts determined by the feeding table of Van Wyk and Scarpa (1999) presented better performance for Pacific white shrimp *L. vannamei* produced in a biofloc system compared to the maximum values of the same table and feed conversion of 1.1 and 1.5. Although this feeding strategy showed better results, this study found that it is still necessary to improve these strategies, since the adjustments of these systems must be made according to the interactions of each unit.

CONFLICT OF INTERESTS

Nothing to declare.

FINANCIAL SUPPORT

Coordenação de Aperfeiçoamento de Pessoal de Nível Superior.

AUTHOR'S CONTRIBUTIONS

Silva, W.A.: investigation, formal analysis, data curation, writing — original draft. Morais, A.P.M.: data curation, software, writing — review & editing. Figueiredo, J.P.V.: investigation, formal analysis, data curation, writing — review & editing. Rafael, R.E.Q.: formal analysis, data curation, writing — review & editing. Oliveira, C.Y.B.: formal analysis, data curation, writing — review & editing. Vieira, F.N.: supervision, project administration, writing — review & editing.

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