Comparative analysis of the culture of pink shrimp Farfantepenaeus brasiliensis and Pacific white shrimp Litopenaeus vannamei in biofloc system

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Abstract

Shrimp farming in Biofloc Technology System (BFT), is already considered as an alternative to the traditional culture system. The bioflocs keep the water quality and can be used as food supplement for shrimp. Most of the production in BFT is based on the Pacific white shrimp *Litopenaeus vannamei*. However, its cultured is limited by the low temperatures. Thus, the in BFT culture potential of native species such as the pink shrimp Farfantepenaeus brasiliensis should be considered. The present study aimed to compare the culture of *F. brasiliensis* and *L. vannamei* in the Grow out phase, in BFT system. The experiment was composed of two treatments: (FB) Grow out of *F. brasiliensis* (LV) Grow out of *L. vannamei*. The study lasted 70 days and was conducted at the Marine Station of Aquaculture from Federal University of Rio Grande, Rio Grande do Sul State, Brazil. The stocking density were of 100 shrimp/m² for both species. The shrimp were fed twice a day with commercial food. Physicochemical parameters of the water were monitored throughout the experimental period. The results showed that all physicochemical parameters of the water remained within the tolerated limits for both species. However, a better zootechnical performance of the shrimp *L. vannamei* compared to *F. brasiliensis* during the growth phase in the BFT was observed. The results point L. vannamei has a higher capacity to catch bioflocs as supplementary food, demonstrate a better response of that species to the BFT system in the Grow out phase compared F. brasiliensis.

1. Introducion

Among the large cultured groups, the crustaceans have been standing out and presenting an important growth in the last few years, contributing almost 10 million tons of the total aquaculture production (FAO 2020). Most of this contribution comes from *Litopenaeus vannamei* shrimp farming, which represents about 52.9% of total world shrimp farming (FAO 2020). *L. vannamei* is a native species from the Eastern Pacific and is distributed from Mexico to Northern coast of Peru. This species presents great robustness and easy adaptation to different culture systems, besides having one of the best zootechnical indexes and great market acceptance (Barbieri Jr. and Ostrensky Neto 2001; FAO 2020; Liao and Chien 2011). Besides achieving high growth and survival rates, it has lower nutritional requirements in terms of protein, when compared to other penaeid species such as *Farfantepenaeus paulensis* and *Farfantepenaeus brasiliensis* (Brazilian native species) (Marchiori 1996; Roubach et al. 2003; Worms 2021).

Despite their higher nutritional requirements, native species may be of interest for aquaculture. *F. brasiliensis*, for example, has potential for growth in confined environments as already shown in some studies (Lopes et al. 2010; Poersch et al. 2006). This species is distributed from North Carolina (USA) to the coast of Rio Grande do Sul (Brazil) (D'Incao 1999; Dias-Neto and Dias 2015) and is among the main fishing resources of the southeastern Brazilian coast (Dias- Neto and Dias 2015). However, one of the main limitations for its production is the lack of a specific commercial feed that meets its nutritional requirements (Roubach et al. 2003), as is the lack of a complete technological package that would guarantee the economic viability of production (Lopes et al. 2009).

Despite its full expansion and economic growth, global aquaculture has still been questioned regarding its sustainability due to the impacts, especially from large amounts of effluents generated and discharged into the environment (Jayanthi et al. 2018). These nitrogen- and phosphate-rich nutrients can accelerate the process of eutrophication of water bodies or be a source of pathogens (Haslun et al. 2012). From this concern, some technologies have already been studied and used, with the purpose of reducing the impact generated by this sector, among them stand out the Biofloc Technology System (BFT), which aims at minimum or zero water exchange (Avnimelech 1999). In this system the carbon: nitrogen ratio of the water is manipulated, in order to stimulate the emergence of microorganisms capable of assimilating and converting the nitrogen excreted by the cultured animals and/or from the leftover feed offered (Avnimelech 2009). It has already been reported by several researchers that this type of system guarantees success in production (Brandão et al. 2021; Reis et al. 2019; Xu and Pan 2012), besides decreasing the discharge of effluents from the environment, it can be classified as a more sustainable way of culture. In addition to the reduction of effluent generation, the microorganisms present in bioflocs can serve as food (Burford et al. 2004; Wasielesky et al. 2006; Krummenauer et al. 2020), making it possible to reduce the protein level in commercial feeds, or even to be a protein supplement for species that require higher values. The ability of penaeid shrimp to consume microorganisms can make this type of food and culture system to have a high success rate. Thompson et al. (1999) reported the importance of bacteria, ciliates and flagellates in the feeding and survival of *F. paulensis* larvae, and Loureiro et al. (2012) using protozoa, rotifers and nematodes as live food for *L. vannamei*, obtained positive results in the zootechnical parameters. However, the aggregate form of microorganisms can provide better consumption efficiency by the cultured shrimp (Martínez-Córdova et al. 2014).

L. vannamei has been one of the main species used for studies in BFT systems, with an already consolidated technological package. Magaña-Gallegos et al. (2018) and Suita et al. (2016) reported that bioflocs are important food sources for this species, both for reproduction and for post-larvae. Krummenauer et al. (2020) reported that the contribution of this food source can vary from 63 to 86% in the growth phase. Few studies have evaluated the zootechnical performance of native species in a BFT system. Some studies have shown the potential of *F. brasiliensis* in this system (Emerenciano et al. 2012; Hostins et al. 2015; Lopes et al. 2012), but they focused on the nursery phase, lacking further research to assess the potential and economic viability of *F. brasiliensis* and other native shrimps in biofloc system, especially in the Grow out phase. In this sense, the objective of this study was to evaluate the potential of rearing pink shrimp *F. brasiliensis* in a BFT system in the Grow out phase.

2. Material And Methods

2.1. Study area

The study was conducted at the Marine Station of Aquaculture Professor Marcos Alberto Marchiori (EMA-FURG), Institute of Oceanography, Federal University of Rio Grande (FURG), located in the city of Rio Grande, Rio Grande do Sul State, Brazil (32 °S, 52 °W).

2.2. Origin of Shrimps

Two species of marine shrimp were used for the research. The species *Litopenaeus vannamei* was purchased as nauplii from Aquatec® located in the state of Rio Grande do Norte, Brazil. Upon arrival at the EMA-FURG, they were kept in the hatchery and nursery sectors until juveniles reached the weight of about 0.7g for the experiment. The second species used in the study was the native *F. brasiliensis*. Shrimps were captured in the northern coast of Santa Catarina State and transported to the maturation sector of EMA-FURG. After seven days of acclimation the shrimp was induced to gonadal maturation to obtain fertilized eggs. Following the 24 hours of incubation, nauplii were then transferred to the hatchery and nursery sectors until they weight about 0.7g necessary to start the experiment.

2.3. Experimental design

The study was conducted in a 582 m² greenhouse from March to June (summer/autumn). The experiment had two treatments that compared the culture of the two species in biofloc system. Treatment LV = *Litopenaeus vannamei* and treatment FB = *Farfantepenaeus brasiliensis*. Juveniles were stocked in 12 tanks (six tanks for each species) of 35 m³ lined with HDPE (1.5mm). Each tank was equipped with a diffused air aeration system, with the air injected by a blower and distributed throughout the tank through micro perforated hoses (Aerotube®). Each tank was equipped with a feeding tray to check daily feed consumption. The stocking density was 100 shrimp/m². The animals were stocked with an initial weight of 0.72 ± 0.37 (*F. brasiliensis*) and 0.78 ± 0.29 (*L. vannamei*).

2.4. Biofloc formation

Before stocking the animals, each experimental unit was inoculated with about 10% of its volume with an inoculum of biofloc water from a previous culture that had already gone through the nitrification process and had a microbial community formed to avoid the high levels of nitrogen (Krummenauer et al. 2014). To maintain the C: N ratio of the water, organic fertilizations were carried out with sugarcane molasses, as proposed by Avnimelech (1999) and Ebeling et al. (2006)

2.5. Water quality management

Throughout the experiment, temperature and dissolved oxygen parameters were monitored daily with an oximeter (YSI® 55) and pH with a digital pH meter (YSI® 60). When pH was below levels indicated for the species (Van Wyk and Scarpa 1999), hydrated lime [$Ca(OH)_2$] was added to the water according to the methodology proposed by Furtado et al. (2016). Total Ammonia Nitrogen (TAN) and Nitrite ($N\text{-}NO_2^-$) levels were monitored daily according to Strickland and Parsons (1972). Nitrate ($N\text{-}NO_3^-$) and phosphate ($P\text{-}PO_4^{-3}$) levels were determined weekly following Aminot and Chaussepied (1983). The concentration of total suspended solids (TSS) and alkalinity were determined, three times a week, according to Strickland and Parsons (1972) and APHA (2012), respectively.

The levels of total suspended solids (TSS) were monitored and maintained according to Gaona et al. (2017), through of the clarification process of the culture water, according to the methodology of Johnson

and Chen (2006) adapted by Gaona et al. (2011). Water turbidity was measured once a week by a turbidimeter (Hach® model 2100P). The salinity and transparency of the water were measured twice a week, the first using an optical refractometer (Atago) and the second with a Secchi disk. The volume of settleable bioflocs was quantified three times a week by means of the Imhoff cone, as described by Eaton et al. (1995).

In order to help maintaining the quality of the culture water, applications of the commercial probiotic (INVE®) were made through two application routes, one applied directly to the water (0.5 ppm/week) and the other mixed in the feed (3.0 g kg^{-1} feed).

2.6. Zootechnical Performance

Weekly shrimp weights was taken from 100 individuals per experimental unit and using a 0.01 g precision scale (MARTE As 1000 C). After biometrics, the feed adjustments were calculated according to the methodology described by Jory et al. (2001). The zootechnical parameters evaluated were:

Final weight (g);

Weekly weight gain (g) (WWG) = (final weight - initial weight) / weeks of culture;

Productivity (kg/m²) = (final biomass - initial biomass) / volume of tank or culture area;

Survival (%) = (final biomass / average individual final weight) / number of individuals stocked) x 100;

Feed conversion rate (FCR) = Amount of feed supplied during the entire culture / (final biomass - initial biomass).

2.7. Scanning Electron Microscopy Analysis

The third maxilliped of both species were prepared for scanning electron microscopy (SEM). The maxilliped samples were washed with 0.2 M sucrose and 0.1 M sodium cacodylate buffer solution for 15 minutes three times. Soon after, they were fixed in a 1.0% osmium tetroxide (OsO_4) solution (1: 1 2.0% osmium tetroxide solution and 0.4 M sodium cacodylate) for three hours at 4ºC and then washed in water bidistilled for 15 minutes twice. After the fixation process, the samples were dehydrated with increasing concentrations of ethanol. Then, for SEM, the maxilliped samples were dried in the critical point apparatus (Emitech K850) mounted on copper supports (stubs) and plated in liquid silver to allow the conduction of electrons. The samples were dried at 26°C and then taken to a metallizer (Emitech K 550) to be covered with a gold surface layer. The sample preparation process was carried out according to EMBRAPA Scanning Electron Microscopy Sample Processing Manual (Castro 2002). At the end of the process, the samples were observed in the Zeiss DSM 940 microscope.

2.8. Statistical Analysis

The data obtained were submitted to the assumptions of normality (Shapiro Wilk) and homoscedasticity (Levene) tests to verify the data distribution. If assumptions were met the data were submitted to one-

way ANOVA (α = 0.05) and when significant differences were detected Tukey's test was applied with 95% reliability level (Zar 2010).

3. Results

3.1. Water quality

The mean values (± SD) of the water quality parameters are described in Table 1.

Table 1
Means (± standard deviation) of the physical and chemical parameters of the water in the culture of *Litopenaeus vannamei* and *Farfantepenaeus brasiliensis* in a biofloc system.

	Treatments	
Parameters	*F. brasiliensis*	*L. vannamei*
Temperature (°C)	25.4 ± 3.1	25.7 ± 3.2
Dissolved oxygen (mg L^{-1})	6.6 ± 0.5	6.5 ± 0.4
pH	8.1 ± 0.2	8.0 ± 0.2
Salinity	32.8 ± 0.7	33.12 ± 0.8
Alkalinity (mg of $CaCO_3$ L^{-1})	157.7 ± 23.3	143.56 ± 22.1
Total suspended solids (mg L^{-1})	298.5 ± 119.7	299.7 ± 128.4
Turbidity (NTU)	105.0 ± 83.9	110.8 ± 90.2
TA- N (mg L^{-1})	0.15 ± 0.11	0.20 ± 0.18
NO_2^-N (mg L^{-1})	0.3 ± 0.2	1.1 ± 1.30
NO_3^- N (mg L^{-1})	17.9 ± 8.8	19.1 ± 9.6
PO^3_4- P (mg L^{-1})	1.43 ± .93	1.30 ± 1.0

The temperature showed no significant differences between treatments ($P > 0.05$) and remained stable and above 28°C until the fifth week of the experiment, and a decrease in temperature was observed until the end of the culture, obtaining average values below 22°C (Fig. 2a). The dissolved oxygen concentration in both treatments remained above 6.0 mg.L^{-1}. Despite the lack of significant differences ($P > 0.05$) between treatments during the entire culture, after the fifth week the FB treatment showed average oxygen levels above the LV treatment. The pH did not differ significantly ($P > 0.05$) between treatments and maintained an average value of 8.05 ± 0.2. Differences in mean salinity values between FB (32.8 ±

0.7) and LV (33.12 ± 0.82) treatments were non-significant ($P > 0.05$). The concentrations of total suspended solids showed a gradual increase since the beginning of the experiment (Fig. 2b) with subsequent decrease of these levels from the sixth week for LV treatment and from the seventh week for FB treatment due to the clarification process performed in the experimental units. TSS levels did not show statistical differences between treatments ($P > 0.05$). The turbidity values did not differ statistically ($P > 0.05$) and showed the same variation pattern as the TSS. The treatments did not present significant differences regarding alkalinity ($P > 0.05$). The mean concentrations were 157.70 ± 23.31 and 143.56 ± 22.15 mg L^{-1} $CaCO_3$ in the FB and LV treatments, respectively.

The concentration of total ammonia nitrogen (TA-N) showed oscillations in both treatments during cultivation with higher levels for treatment LV (Fig. 1a), though differences were non-significant ($P > 0.05$). Nitrite levels showed no significant differences between treatments ($P > 0.05$). However, it was observed that after the 50th day of the experiment the concentration of this nutrient increased until the end of the experiment in the LV treatment only (Fig. 1b). Nitrate and phosphate concentrations showed no significant differences between treatments ($P > 0.05$). Nitrate presented a gradual increase along the cultivation with a maximum values of 30 mg L^{-1} at the end of the culture (Fig. 1c). Low phosphate levels were found throughout the experiment.

3.2. Scanning Electron Microscopy Images

A total of 30 scanning electron microscopy photos of the third maxilliped of the shrimp *Litopenaeus vannamei* (15 images) and *Farfantepenaeus brasiliensis* (15 images) were analyzed. The images had magnification from 32x up to 5000x. Endopodited presented longer and feathery bristles in *L. vannamei* and shorter and tighter bristles *F. brasiliensis* (Fig. 4).

3.3. Zootechnical performance

The indices of zootechnical performance for both treatments are presented in Table 2.

Table 2
Mean values (± standard deviation) of the zootechnical performance of *Litopenaeus vannamei* and *Farfantepenaeus brasiliensis* shrimp cultured in biofloc system. Different letters superscript on the same line indicates significant differences ($P < 0.05$) between treatments.

	Treatments	
Parameters	*F. brasiliensis*	*L. vannamei*
Initial weight (g)	0.72 ± 0.37 ^{a}	0.78 ± 0.29^{a}
Final weight (g)	3.96 ± 1.40 ^{a}	11.28 ± 1.89^{b}
Weekly growth (g week^{-1})	0.32 ± 0.20^{a}	1.05 ± 0.62^{b}
Final biomass (kg)	9.34 ± 1.68^{a}	40.49 ± 2.55^{b}
Survival (%)	64.50 ± 9.68^{a}	98.12 ± 6.12^{b}
Productivity (kg m^{-2})	0.26 ± 0.05^{a}	1.12 ± 0.07^{b}
Feed Conversion Ratio	5.45 ± 1.34^{a}	1.43 ± 0.06^{b}

Initial weights (g) of *F. brasiliensis* (0.72 ± 0.37) and *L. vannamei* (0.78 ± 0.29) were similar ($P > 0.05$). However, final weights of *L. vannamei* (11.28 ± 1.89 – LV treatment) was significantly higher ($P < 0.05$) compared to the *F. brasiliensis* (3.96 ± 1.40 – FB treatment) (Fig. 3b). Similarly, the weekly growth rate (Fig. 3a) was also higher ($P < 0.05$) for *L. vannamei*.

Significant differences ($P < 0.05$) were found between the two species in terms of biomass, survival rate and productivity, with the means of these parameters being 9.34 ± 1.68 kg; 64.50 ± 9.68% and 0.26 ± 0.05 kg/m² for the FB treatment and 40.49 ± 2.55 kg; 98.12 ± 6.12% and 1.12 ± 0.07 kg m^{-2} for the LV treatment, respectively. The FCR was significantly ($P < 0.05$) higher for *F. brasiliensis*.

4. Discussion

Water quality parameters remained within the range suitable for the growth of both species (Van Wyk and Scarpa 1999). Temperature is one of the most important parameters, as it can affect food consumption, growth and survival of the species in culture environments (Hostins et al. 2015; Wang et al. 2006). According to Van Wyk and Scarpa (1999), the Pacific white shrimp *L. vannamei* can survive in a wide temperature range (15–35°C), however, for the best zootechnical performance it should be between 28–32°C (Walker et al. 2011). Zuñiga et al. (1988) found that growth of *L. vannamei* was negatively affected at temperatures below 23°C and Ponce-Palafox et al. (1997) observed that temperatures of 20°C negatively affect the species' food consumption and growth.

There is little information regarding the ideal temperature range for growth and survival of *F. brasiliensis*, especially in the grow out phase. However, it is known that native species, both *F. brasiliensis* and *F. paulensis* show greater tolerance to low temperatures when compared to *L. vannamei* (Poersch et al. 2006; Wasielesky Jr. et al. 2016). According to Hostins et al. (2015), evaluating the effect of temperature in the nursery stage, found that the best temperature for their growth is 27°C. The average temperature of the present study was 25.5°C, being within the acceptable range for the growth of both cultivated species. During the first weeks of culture, the average temperature in both treatments was near 29°C, in the optimal range for growth. However, there was a gradual decrease in temperature starting in the fifth week, reaching 21°C at end of the experiment. The progressive decline in temperature throughout the second half of the experiment period was one of the main factors responsible for the decrease in weekly weight gain and growth of both species, especially *L. vannamei*. The reported temperature drop was caused by successive cold fronts (coming from the South) that passed through the region where the experiment was carried out.

Dissolved oxygen (DO) is a key parameter for successful shrimp culture (Zhang et al. 2006) and DO concentrations above 5.0 mg L^{-1} are recommended (Durai et al. 2021; Van Wyk and Scarpa 1999). In BFT systems, the DO requirement is higher, as besides the consumption by the shrimp, there is an additional consumption by the microorganisms present in the bioflocs (Cohen et al. 2005; De Schryver et al. 2008; Hargreaves 2013). In the present study, the average DO concentration was 6.5 mg L^{-1}, above the recommended level for shrimp culture throughout the experiment. The pH, alkalinity, and salinity were within the values recommended by Van Wyk and Scarpa (1999).

The continuous monitoring of TSS concentration in BFT systems is essential for the maintenance of water quality as well as for the best zootechnical performance of the shrimps (Avnimelech 2009; Gaona et al. 2011; Samocha et al. 2007). In this study, there were no TSS significant differences ($p > 0.05$) between treatments and were within the recommended range for penaeid species (Gaona et al. 2017, 2011; Schveitzer et al. 2013). Although it does not have a recommended value for *F. brasiliensis*, the TSS values were similar to that found by De Souza et al. (2011); Emerenciano et al. (2012); Hostins et al. (2015) for culture in biofloc system. From the sixth and seventh weeks for the LV and the FB treatments, respectively, the clarification process was started aiming at decreasing the TSS concentration as suggested by Gaona et al. (2011) and by Zemor et al. (2019). According to Vinatea et al. (2010), turbidity has a direct relationship with TSS concentration as an escalation in suspended particles increases turbidity in the culture water, decreasing light penetration. In the present study, turbidity did not show significant differences between treatments and followed the variation of TSS throughout the experiment.

Ammonia is the main nitrogenous form of crustacean excreta (Regnault 1987) and in high concentration can be toxic and harmful to shrimp, as can be its metabolites (nitrite and nitrate) (Furtado et al. 2015; Lin and Chen 2001, 2003). The values of these nitrogenous compounds found in this study, remained within tolerable limits for both species (Campos et al. 2015; Van Wyk and Scarpa 1999), causing no negative effects on the zootechnical performance of farmed shrimp. Although from the 50th experimental day, the nitrite concentration in the LV treatment gradually increased, remaining higher compared to the FB

treatment until the end of the experiment (Fig. 1b), these levels did not exceed the recommended limit for *L. vannamei* (Lin and Chen 2003). The continuous clarification process may have caused this increase in nitrite concentration in the LV treatment. It is possible to observe that from the 6th week of culture, when the solids removal process started in this treatment, the nitrite concentration also started to increase. The intense clarification to remove TSS may have also been responsible for removing heterotrophic and nitrifying bacteria present in the biofloc, leading to an increase of nitrite in the system. Ray et al. (2010) observed that the removal of suspended solids decreases the bacterial abundance from the microbial community in the BFT system. It is therefore likely that the intense clarification process from the 6th week onwards caused a reduction of bacteria and a greater increase in the total ammonia nitrogen in the water as the bacteria are responsible for its removal (Ebeling et al. 2006).

The concentration and behavior of orthophosphate in a culture are related to the constant nutrient input, with the decomposition of uneaten feed and the excretion of cultured organisms being the main source of phosphorus in the system (Barak et al. 2003; Samocha et al. 2017). Samocha et al. (2017) reported that they found orthophosphate concentrations of 32 mg L^{-1} in culture farms with no harm to shrimp performance. In this present study, the average orthophosphate concentration found in both treatments was much lower than reported by Samocha et al. (2017).

The results of zootechnical performance showed significant differences among treatments, with higher values of final weight, weekly weight gain, biomass, survival and productivity for *L. vannamei* when compared to *F. brasiliensis* treatment. Some studies have shown good zootechnical performance results for *F. brasiliensis* cultured in biofloc system. However, these encouraging results are reported only in the nursery phase (De Souza et al. 2011; Emerenciano et al. 2012; Hostins et al. 2015). Information on the grow out in the BFT system is lacking for both *F. brasiliensis* and *L. vannamei.* Several studies corroborate the results regarding the adaptability of later species in this culture system (Brol et al. 2021; Krummenauer et al. 2014; Reis et al. 2019).

Stocking density is a factor that plays an important role in survival rate and other zootechnical parameters. In this study, significant differences were found in survival rates between LV and FB treatments. In other comparative studies survival rates were not statistically different (e.g. Peixoto et al. 2003; Sandifer et al. 1993), though stocking densities were lower compared to the present study. Da Silveira et al. (2020) and Krummenauer et al. (2011) tested higher stocking densities than that used in this study (for *L. vannamei*) and found no significant differences in survival rates between treatments. Lopes et al. (2012) observed that *F. brasiliensis* could be reared at densities of up to 600 m^{-2} in a BFT system in the nursery phase without affecting survival. Although there are no studies showing the effects of different stocking densities of this species in the grow out phase, Krummenauer et al. (2006) analyzed different stocking densities for the native pink shrimp, *F. paulensis* and recommended that this species can be reared at stocking densities between 40 to 120 shrimp m^{-2}, obtaining suitable zootechnical performance indices. In the present study, the density used was 100 shrimp m^{-2}, suggesting that the survival rates of both species reared in the present study were not affected by the stocking density used.

Determining the protein digestibility of feedstuffs that make up shrimp feed is important for developing balanced, high quality diets (Ayisi et al. 2017; Cruz-Suárez et al. 2009; Lee and Lawrence 1997). In addition, effective diets based on the response of different shrimp species can offer many advantages, such as a better feed conversion rate and faster growth (D'Abramo et al. 1997). In this study, both treatments were fed with commercial feed specifically developed for *L. vannamei* based on the nutritional requirements of this species. This possibly favored the occurrence of lower AFCR rates for *L. vannamei* compared to *F. brasiliensis.*

Regarding the utilization of biofloc as food supplement for these species, it seems that the contribution was greater for the *L. vannamei*. Bufford et al. (2004) also showed a significant contribution of biofloc for the nutrition of this species. The structure of its third maxilliped probably has contributed to the better nutrition and overall zootechnical performance of *L. vannamei*. This appendix is the largest and outermost buccal apparatus in decapod crustaceans (Eap et al. 2020; Garm 2004) and performs several functions, including the manipulation of food particles (Alexander et al. 1980; Parra-Flores et al. 2019). In *L. vannamei* the endopods of the third maxilliped are covered by longer, more abundant and feathered bristles (Fig. 4a and 4b) that facilitate the capture of biofloc particles, whereas *F. brasiliensis* (Fig. 4c and 4d) has simpler and shorter bristles, that makes particles' capture more difficult. Kim et al. (2015) also observed the same difference between the third maxilliped of *L. vannamei* and other penaeid species and showed that the former has a higher efficiency in capturing biofloc. Krummenauer et al. (2020) using the stable isotope analyses showed that bioflocs can contribute up to 86% of the feed of *L. vannamei* in the grow out phase. These results corroborate those found in this study and show that *L. vannamei* can have better performances in this type of culture system.

5. Conclusion

The *L. vannamei* showed better results in zootechnical performance when compared to the pink shrimp *F. brasiliensis* in the Grow out phase in the BFT system. The studies already carried out with *F. brasiliensis* in the nursery phase in biofloc indicate its potentiality for culture in BFT system. However, significant advances are still needed to make the culture of native species feasible, such as further studies on their nutritional needs, protein digestibility, genetic improvement, and the consumption and utilization of biofloc. This study corroborates with studies already conducted on the adaptability of *L. vannamei* to the biofloc system.

Statements & Declarations

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Author contributions:

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Conflict of interest:

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this article.

Code availability:

Not applicable.

Data Availability:

All data generated or analyzed during this study are included in this published article.

References

1. Alexander C G, Hindley J P R, Jones S G (1980) Structure and function of the third maxillipeds of the banana prawn *Penaeus merguiensis*. Marine Biology 58: 245–249. https://doi.org/10.1007/BF00390772
2. Aminot A E, Chaussepied M (1983). Manuel des analyses chimiques en milieu marin. Brest, Paris.
3. APHA American Public Health Association, AWWA American Water Works Association, WEF Water Enviroment Federation (2012). Standard Methods for the Examination of Water and Wastewater. American Public Health Association, Washinghton.
4. Avnimelech Y (2009) Biofloc Technology- A Pratical Guide Book. The world Aquaculture Society, Louisiana.
5. Avnimelech Y (1999) Carbon/ nitrogen ratio as a control element in aquaculture systems. Aquaculture 176: 227–235. https://doi.org/10.1016/S0044-8486(99)00085-X
6. Ayisi C L , Hua X, Apraku A, Afriyie G, Kyei B A (2017) Recent Studies Toward the Development of Practical Diets for Shrimp and Their Nutritional Requirements. HAYATI Journal of Biosciences 24: 109–117. https://doi.org/10.1016/j.hjb.2017.09.004
7. Barak Y, Cytryn E, Gelfand I, Krom M, Van Rijn J (2003) Phosphorus removal in a marine prototype, recirculating aquaculture system. Aquaculture 220: 313–326. https://doi.org/10.1016/S0044-

8486(02)00342-3

8. Barbieri Jr R C, Ostrensky Neto A (2001) Camarões Marinhos: Reprodução Maturação e Larvicultura. Aprenda Fácil, Viçosa.
9. Brandão H, Xavier Í V, Santana G K K , Santana H J K, Krummenauer D, Wasielesky W (2021) Heterotrophic versus mixed BFT system: Impacts on water use, suspended solids production and growth performance of *Litopenaeus vannamei*. Aquacultural Engineering 95: 102194. https://doi.org/10.1016/j.aquaeng.2021.102194
10. Brol J, Müller L, Prates E C A, de Farias B S, Pedrosa V F, de Almeida Pinto L A, Sant'anna Cadaval T R, Tesser M B, Wasielesky W, Ventura-Lima J (2021) Dietary chitosan supplementation in *Litopenaeus vannamei* reared in a biofloc system: Effect on antioxidant status facing saline stress. Aquaculture 544: 7377034. https://doi.org/10.1016/j.aquaculture.2021.737034
11. Burford M A, Thompson P J, Mcintosh R P, Bauman R H , Pearson D C (2004) The contribution of flocculated material to shrimp (*Litopenaeus vannamei*) nutrition in a high-intensity, zero-exchange system. Aquaculture 232: 525–537. https://doi.org/10.1016/S0044-8486(03)00541-6
12. Campos B R, Furtado P S , D'Incao F, Poersch L, Wasielesky W (2015) The chronic toxicity of ammonia, nitrite and nitrate on juvenile *Farfantepenaeus brasiliensis* (crustacea: decapoda). Boletim do Instituto de Pesca 41: 261–269.
13. Castro L A S de (2002) Processamento de Amostras para Microscopia Eletrônica de Varredura. Embrapa Clima Temperado, Pelotas.
14. Cohen J M, Samocha T M , Fox J M , Gandy R L , Lawrence A L (2005) Characterization of water quality factors during intensive raceway production of juvenile *Litopenaeus vannamei* using limited discharge and biosecure management tools. Aquacultural Engineering 32: 425–442. https://doi.org/10.1016/j.aquaeng.2004.09.005
15. Cruz-Suárez L E, Tapia-Salazar M, Villarreal-Cavazos D, Beltran-Rocha J, Nieto-López M G, Lemme A, Ricque-Marie D (2009) Apparent dry matter, energy, protein and amino acid digestibility of four soybean ingredients in white shrimp *Litopenaeus vannamei* juveniles. Aquaculture 292: 87–94. https://doi.org/10.1016/j.aquaculture.2009.03.026
16. D'Abramo L R, Conklin D E , Akiyama D M (1997) Crustacean Nutrition. Baton rouge: World Aquaculture Society, Louisiana.
17. D'Incao F (1999) Subordem Dendrobranchiata (camarões marinhos), in: Buckup L, Bond-Buckup G. (Eds.) Crustaceos do Rio Grande do Sul, 1st ed. Editora da FURG, Porto Alegre, pp 229–275.
18. Da Silveira L G P, Krummenauer D, Poersch L H, Rosas V T, Wasielesky W (2020). Hyperintensive stocking densities for *Litopenaeus vannamei* grow-out in biofloc technology culture system. Journal of the World Aquaculture Society 51: 1290–1300. https://doi.org/10.1111/jwas.12718
19. 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: 125–137. https://doi.org/10.1016/j.aquaculture.2008.02.019

20. De Souza D M, Suita S M, Leite F P L, Romano L A, Wasielesky W, Ballester E L C (2011) The use of probiotics during the nursery rearing of the pink shrimp *Farfantepenaeus brasiliensis* (Latreille, 1817) in a zero exchange system. Aquaculture Research 43: 1828–1837. https://doi.org/10.1111/j.1365-2109.2011.02992.x
21. Dias-Neto J, Dias J de F O (2015) O Uso da Biodiversidade Aquática no Brasil: Uma Avaliação com foco na pesca, IBAMA, Brasilia.
22. Durai V, Alagappan M, Yuvarajan P (2021) Importance of Water Quality in Whiteleg Shrimp (*Penaeus vannamei*) Farming. AgriCos e-Newsletter 2: 17–20.
23. Eap D, Correa S, Ngo-Vu H, Derby C D (2020) Chemosensory basis of feeding behavior in pacific white shrimp, *Litopenaeus vannamei*. Biological Bulletin 239: 115–131. https://doi.org/10.1086/710337
24. Eaton A, Cleserci L, Greeberg A (1995) Standard Methods for the Examination of Water and Waste Water, 10th ed. Health associacion, Washington.
25. 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: 346–358. https://doi.org/10.1016/j.aquaculture.2006.03.019
26. Emerenciano M, Ballester E L C , Cavalli R O, Wasielesky W (2012) Biofloc technology application as a food source in a limited water exchange nursery system for pink shrimp *Farfantepenaeus brasiliensis* (Latreille , 1817). Aquaculture Research 43: 447–457. https://doi.org/10.1111/j.1365-2109.2011.02848.x
27. FAO (2020) The State of World Fisheries and Aquaculture 2020- Sustainabily in action, Food and Agriculture Organization of the United Nations. Rome. https://doi.org/10.4060/ca9229en
28. Furtado P, Campos B R , Serra F P, Klosterhoff M, Romano L A (2015) Effects of nitrate toxicity in the Pacific white shrimp, *Litopenaeus vannamei* , reared with biofloc technology (BFT). Aquaculture International 23: 315–327. https://doi.org/10.1007/s10499-014-9817-z
29. Gaona C A P, Almeida M S De, Viau V, Poersch L, Wasielesky Jr W (2017) Effect of different total suspended solids levels on a *Litopenaeus vannamei* (Boone , 1931) BFT culture system during biofloc formation. Aquaculture Research 48: 1070–1079. https://doi.org/10.1111/are.12949.
30. Gaona C A P , Poersch L H, Krummenauer D, Foes G K, Wasielesky Jr W (2011) The Effect of Solids Removal on Water Quality , Growth and Survival of *Litopenaeus vannamei* in a Biofloc Technology Culture System. International Journal of Recirculating Aquaculture 12: 54–73.
31. Garm A (2004) Mechanical functions of setae from the mouth apparatus of seven species of decapod crustaceans. Journal of Morphology 260: 85–100. https://doi.org/10.1002/jmor.10213.
32. Hargreaves J A (2013). Biofloc Production Systems for Aquaculture. In Avnimelech Y, et al. (ed) Biofloc Technology: A Pratical Guidebook, 3rd ed. Southern Regional Aquaculture Center, Lousiana, pp 1–12.
33. Haslun J, Correia E S, Strychar K, Morris T C, Samocha T M (2012) Caracterization of Bioflocs in a No Water Exchange Super-intensive System for production of Food Size Pacific White Shrimp

Litopenaeus vannamei. International Journal of Aquaculture 2: 29–39. https://doi.org/10.5376/ija.2012

34. Hostins B, Braga A, Lopes D L A, Wasielesky W, Poersch L H (2015) Effect of temperature on nursery and compensatory growth of pink shrimp *Farfantepenaeus brasiliensis* reared in a super-intensive biofloc system. Aquacultural Engineering 66: 62–67. https://doi.org/10.1016/j.aquaeng.2015.03.002
35. Jayanthi M, Thirumurthy S, Muralidhar M, Ravichandran P (2018) Impact of shrimp aquaculture development on important ecosystems in India. Global Environmental Change 52: 10–21. https://doi.org/10.1016/j.gloenvcha.2018.05.005
36. Johnson W, Chen S (2006) Performance evaluation of radial/vertical flow clarification applied to recirculating aquaculture systems. Aquacultural Engineering 34: 47–55. https://doi.org/10.1016/j.aquaeng.2005.05.001
37. Jory D E, Cabrera T R, Dugger D M, Fegan D, Lee P G, Lawrence A L, Jackson R P, Mcintosh R P, Castaneda J (2001) A global review of srhip feed management: Status and perpectives. In: Browdy, C L, Jory D E. (eds.) The New Wave: Proceedings of the Special Session on Sustainable Shrimp Culture, Aquaculture. The world Aquaculture Society, Lousiana, pp 104–152.
38. Kim S K , Guo Q, Jang I K (2015) Effect of biofloc on the survival and growth of the postlarvae of three penaeids (*Litopenaeus vannamei*, *Fenneropenaeus chinensis*, and *Marsupenaeus japonicus*) and their biofloc feeding efficiencies, as related to the morphological structure of the third ma. Journal of Crustacean Biology 35: 41–50. https://doi.org/10.1163/1937240X-00002304
39. Krummenauer D, Abreu P C, Poersch L, Reis P A C P , Suita S M , dos Reis W G, Wasielesky W (2020) The relationship between shrimp (*Litopenaeus vannamei*) size and biofloc consumption determined by the stable isotope technique. Aquaculture 529: 735635. https://doi.org/10.1016/j.aquaculture.2020.735635
40. Krummenauer D, Peixoto S, Cavalli R O, Poersch L H, Wasielesky Jr W (2011) Superintensive Culture of White Shrimp, *Litopenaeus vannamei*, in a Biofloc Technology System in Southern Brazil at Different Stocking Densities. Journal of the World Aquaculture Society 42: 726–733. https://doi.org/10.1111/j.1749-7345.2011.00507.x
41. Krummenauer D, Samocha T, Poersch L, Lara G, Wasielesky W (2014) The reuse of water on the culture of pacific white shrimp, *Litopenaeus vannamei*, in BFT system. Journal of the World Aquaculture Society 45: 3–14. https://doi.org/10.1111/jwas.12093
42. Krummenauer D, Wasielesky W, Cavalli R O, Peixoto S, Zogbi P R (2006) Viabilidade do cultivo do camarão-rosa *Farfantepenaeus paulensis* (Crustácea, Decapoda) em gaiolas sob diferentes densidades durante o outono no sul do Brasil. Ciência Rural 36: 252–257. https://doi.org/10.1590/s0103-84782006000100039
43. Lee P G, Lawrence A L (1997) Digestibility. In: D'Abramo L R, Conklin D E (eds.), Crustacean Nutrition: Advances in World Aquaculture. World Aquaculture Society, Los Angeles, pp. 194–260
44. Liao I C , Chien Y (2011) The Pacific White Shrimp, *Litopenaeus vannamei*, in Asia: The World's Most Widely Cultured Alien Crustacean. In: Galil B, Clark P, C J (ed.), In: The Wrong Place - Alien Marine

Crustaceans: Distribution, Biology and Impacts Invading Nature, 1st ed, Springer Dordrecht, pp. 489–519. https://doi.org/10.5860/choice.49-3259.

45. Lin Y C, Chen J C (2001) Acute toxicity of ammonia on *Litopenaeus vannamei* (Boone, 1931) juveniles at different salinity levels. Journal of Experimental Marine Biology and Ecology 259: 109–119. https://doi.org/10.1016/S0022-0981(01)00227-1.
46. Lin Y, Chen J (2003) Acute toxicity of nitrite on *Litopenaeus vannamei* (Boone, 1931) juveniles at different salinity levels. Aquaculture 224: 193–201. https://doi.org/10.1016/S0044-8486(03)00220-5
47. Lopes D L de A, Suita S M, Bueno C, Wasielesky Jr W, Poersch L H (2012) Determinaçãoda da densidade de estocagem ótima do camarão rosa *Farfantepenaeus brasiliensis* produzido em tecnologia de bioflocos durante a fase de berçário. Atlântica 34: 113–120. https://doi.org/10.5088/atl.2012.34.2.113
48. Lopes D L de A, Wasielesky Junior W, Ballester E C, Peixoto S R M (2009) Análise comparativa da criação dos camarões-rosa *Farfantepenaeus brasiliensis* e *Farfantepenaeus paulensis* criados em gaiolas em ambiente estuarino. Ciência Rural 39: 1540–1546. https://doi.org/10.1590/s0103-84782009000500036
49. Lopes D L de A, Ballester E L C, Wasielesky Jr W, Peixoto S R M (2010) Avaliação da performance Reprodutiva de Fêmeas Selvagens do Camarão- Rosa *Farfantepenaeus brasiliensis* (Crustácea: Decapoda) em Laboratório. Atlântica 32: 177–182. https://doi.org/10.5088/atl.2010.32.2.177
50. Loureiro C K, Wasielesky Jr W, Abreu P C (2012) The use of protozoan, rotifers and nematodes as live food for shrimp raised in bft system. Atlântica 34: 5-12. https:// doi: 10.5088/atl.2012.34.1.5
51. Magaña- Gallegos E, Gonzáles-Zúñiga R, Cuzon G, Arevalo M, Pacheco E, Valenzuela M A, Gaxiola G, Chan-Vivas E, López- Aguiar K, Noreña-Barroso E (2018) Nutritional Contribution of Biofloc within the Diet of Grow out and Broodstock of *Litopenaeus vannamei*, Determined by Stable Isotopes and Fatty Acids. Journal of the World Aquaculture Society 49: 919- 932. https://doi-org.ez40.periodicos.capes.gov.br/10.1111/jwas.12513.
52. Marchiori M A (1996) Guia ilustrado de maturação e larvicultura do camarão-rosa *Penaeus paulensis* Pérez-Farfante. Editora da FURG, Rio Grande.
53. Martínez-Cordova L R , Emerenciano M, Miranda-Baeza A , Martínez- Porchas M (2014) Microbial-based systems for aquaculture of fish and shrimp: an updated review. Reviews in Aquaculture 6: 1-18. https// doi: 10.1111/raq.12058.
54. Parra-Flores A, Ponce- Palafox J, Spanopoulos- Hernández M, Martinez- Cardenas L (2019) Feeding behavior and ingestion rate of juvenile shrimp of the genus *Penaeus* (Crustacea: Decapoda). Med Crave 3: 111–113. https://doi.org/10.15406/oajs.2019.03.00140
55. Peixoto S, Wasielesky W, Louzada L (2003) Comparative analysis of pink shrimp, *Farfantepenaeus paulensis*, and pacific white shrimp, *Litopenaeus vannamei*, culture in extreme Southern Brazil. Journal of Applied Aquaculture 14: 101–111. https://doi.org/10.1300/J028v14n01_07
56. Poersch L, Cavalli R O, Wasielesky W, Castello J P, Peixoto S R M (2006) Perspectivas para o desenvolvimento dos cultivos de camarões marinhos no estuário da Lagoa dos Patos, RS. Ciencia

Rural 36: 1337–1343. https://doi.org/10.1590/S0103-84782006000400051

57. Ponce-Palafox J, Martinez-Palacios C A, Ross L G (1997) The effects of salinity and temperature on the growth and survival rates of juvenile white shrimp, *Penaeus vannamei*, (Boone, 1931). Aquaculture 157: 107–115. https://doi.org/10.1016/S0044-8486(97)00148-8
58. Ray A J, Seaborn G, Leffler J W, Wilde S B , Lawson A , Browdy C L (2010) Characterization of microbial communities in minimal-exchange, intensive aquaculture systems and the effects of suspended solids management. Aquaculture 310: 130–138. https://doi.org/10.1016/j.aquaculture.2010.10.019
59. Regnault M (1987) Nitrogen Excretion in marine and fresh-water crustacea. Biology Review 62: 1–24. https://doi.org/10.1111/j.1469-185X.1987.tb00623.x
60. Reis W G, Wasielesky W, Abreu P C, Brandão H, Krummenauer D (2019) Rearing of the Pacific white shrimp *Litopenaeus vannamei* (Boone, 1931) in BFT system with di ff erent photoperiods : Effects on the microbial community, water quality and zootechnical performance. Aquaculture 508: 19–29. https://doi.org/10.1016/j.aquaculture.2019.04.067
61. Roubach R, Correia E, Zaiden S, Martino R, Cavalli R O (2003) Aquaculture in Brazil. World Aquaculture Society, Baton Rouge, 34: 28–35.
62. Samocha T M, Patnaik S, Speed M, Ali A, Burger J M, Almeida R V, Ayub Z, Harisanto M, Horowitz A, Brock D L (2007) Use of molasses as carbon source in limited discharge nursery and grow-out systems for *Litopenaeus vannamei*. Aquacultural Engineering 36: 184–191. https://doi.org/10.1016/j.aquaeng.2006.10.004
63. Samocha T M, Prangnell D I, Hanson T R, Treece G D, Morris T C, Castro L F, Staresinic N (2017) Design and operation of super intensive, biofloc-dominated systems for indoor production of the Pacific white shrimp, Litopenaeus vannamei- The Texas A&M Agrilife Research experience, The World Aquaculture Society, Louisiana.
64. Sandifer P A, Hopkins J S , Stokes A D, Browdy C L (1993) Preliminary Comparisons of the Native *Penaeus setiferus* and Pacific *Penaeus vannamei* White Shrimp for Pond Culture in South Carolina, USA. Journal of the World Aquaculture Society 24: 295–303. https://doi.org/10.1111/j.1749-7345.1993.tb00161.x
65. Schveitzer R, Arantes R, Costodio P, Espírito C M, Vinatea L, Seiffert W Q, Andreatta, E (2013) Effect of different biofloc levels on microbial activity, water quality and performance of *Litopenaeus vannamei* in a tank system operated with no water exchange. Aquacultural Engineering 56: 59–70. https://doi.org/10.1016/j.aquaeng.2013.04.006
66. Strickland J D H, Parsons T R (1972) A Practical Handbook of Seawater Analysis, Fisheries research board of Canadá. Supply and services Canadá, 1st ed, Otawa. https://doi.org/http://dx.doi.org/10.14219/jada.archive.1932.0107
67. Suita S M, Braga A , Ballester E, Cardozo A, Abreu P C, Wasielesky Jr W (2016) Contribution of bioflocs to the culture of *Litopenaeus vannamei* post-larvae determined using stable isotopes. Aquaculture International 24: 1473- 1487. https://doi.org/10.1007/s10499-016-0006-0.

68. Thompson F L, Abreu P C, Cavalli R O (1999) The use of microorganisms as food source for *Penaeus paulensis* larvae. Aquaculture 174: 139–153. https://doi.org/10.1016/S0044-8486(98)00511-0
69. Van Wyk P, Scarpa J (1999) Water Quality Requirements and Management. In: Van Wyk P, et al. (ed) Farming Marine Shrimp in Recirculatiing Fresh Water Systems. Florida.
70. Vinatea L, Gálvez A O, Browdy C L, Stokes A, Venero J, Haveman J, Lewis B L , Lawson A, Shuler A, Leffler J W (2010) Photosynthesis, water respiration and growth performance of Litopenaeus vannamei in a super-intensive raceway culture with zero water exchange: Interaction of water quality variables. Aquacultural Engineering 42: 17–24. https://doi.org/10.1016/j.aquaeng.2009.09.001
71. Walker S J, Neill W H, Lawrence A L, Gatlin D M (2011) Effects of temperature and starvation on ecophysiological performance of the Pacific white shrimp (*Litopenaeus vannamei*). Aquaculture 319: 439–445. https://doi.org/10.1016/j.aquaculture.2011.07.015
72. Wang W N, Wang A L, Liu Y, Xiu J, Liu Z B, Sun R Y (2006) Effects of temperature on growth, adenosine phosphates, ATPase and cellular defense response of juvenile shrimp *Macrobrachium nipponense*. Aquaculture 256: 624–630. https://doi.org/10.1016/j.aquaculture.2006.02.009
73. Wasielesky Jr W, Jensen L, Cavalli R O , Peixoto S R M , Santos M H S , Poersch L H (2016) A qualidade da água em um cultivo de *Farfantepenaeus paulensis* em cercado no estuário da Lagoa dos Patos, in: Wasielesky Jr., W., Poersch, L.H. (Ed.), Cultiivo de Camarões em Gaiolas e Cercados No Estuário Da Lagoa Dos Patos. Editora da FURG, Rio Grande, pp. 349–360.
74. Worms Editorial Board (2021) World Register of Marine Species [WWW Document]. Worms Editorial Board. https://doi.org/10.14284/170. Accessed on October 14, 2020.
75. Xu W J, Pan L Q (2012) Effects of bioflocs on growth performance, digestive enzyme activity and body composition of juvenile *Litopenaeus vannamei* in zero-water exchange tanks manipulating C/N ratio in feed. Aquaculture 356–357: 147–152. https://doi.org/10.1016/j.aquaculture.2012.05.022
76. Zar, J., 2010. Biostatistical Analysis. Prentice Hall, 5th ,Upper Saddle River:
77. Zemor J C, Wasielesky W, Fóes G K , Poersch L H (2019) The use of clarifiers to remove and control the total suspended solids in large-scale ponds for production of *Litopenaeus vannamei* in a biofloc system. Aquacultural Engineering 85: 74–79. https://doi.org/10.1016/j.aquaeng.2019.03.001
78. Zhang P, Zhang X, Li J, Huang G (2006) The effects of body weight, temperature, salinity, pH, light intensity and feeding condition on lethal DO levels of whiteleg shrimp, *Litopenaeus vannamei* (Boone, 1931). Aquaculture 256: 579–587. https://doi.org/10.1016/j.aquaculture.2006.02.020
79. Zuñiga O, Ramos R, Wilson P, Lión M (1988) Introducción, aclimatación y crecimiento dde los camarones *Penaeus vannamei* e *Penaeus stylirostris* en el norte de Chile. Estudios Oceanológicos 7:59–69.

Figures

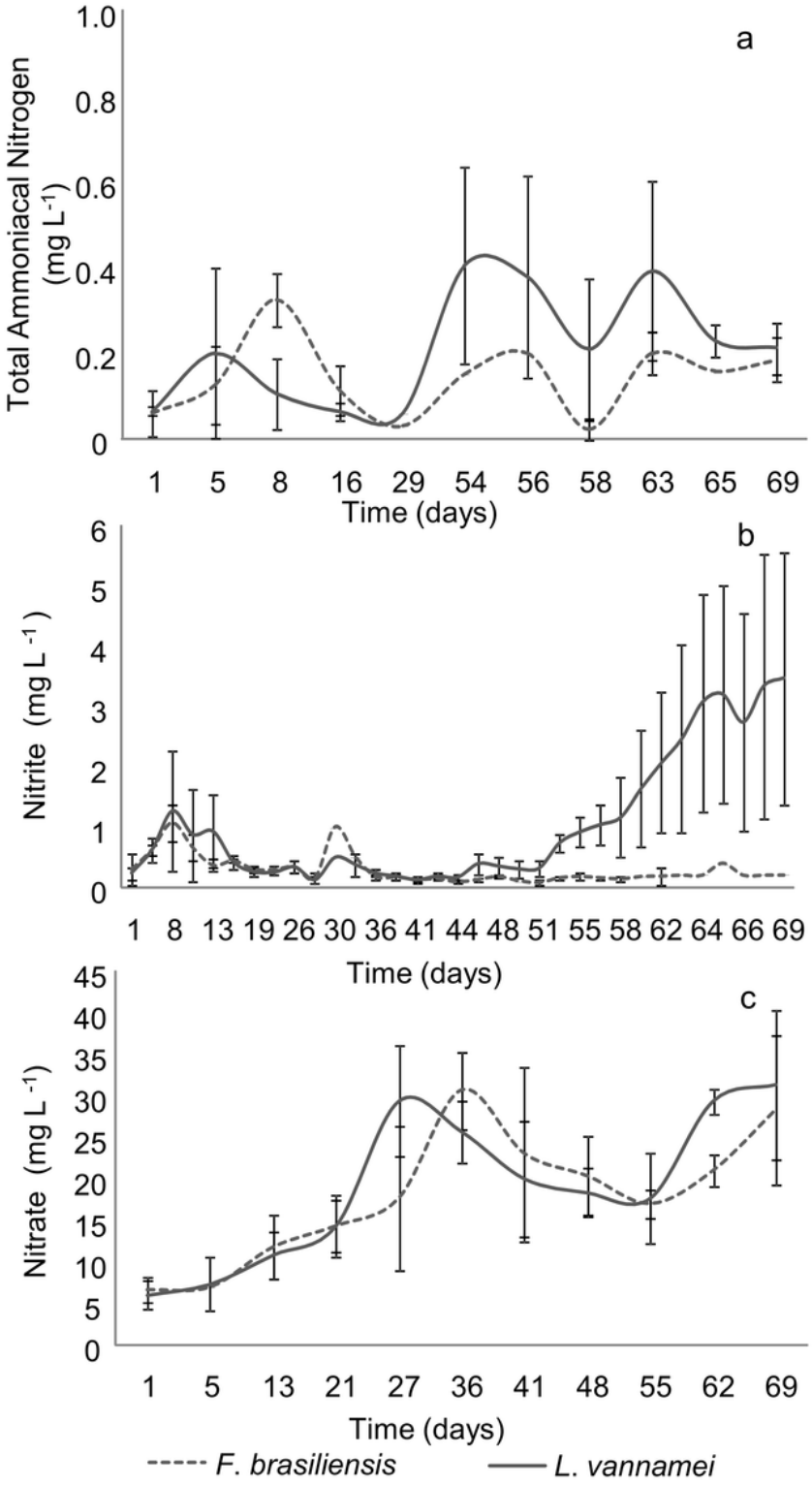

Figure 1

Variations (means ± standard deviation) of concentrations of (a) total ammonia nitrogen (b) nitrite (c) nitrate during the culture of Litopenaeus vannamei and Farfantepenaeus brasiliensis in a biofloc system

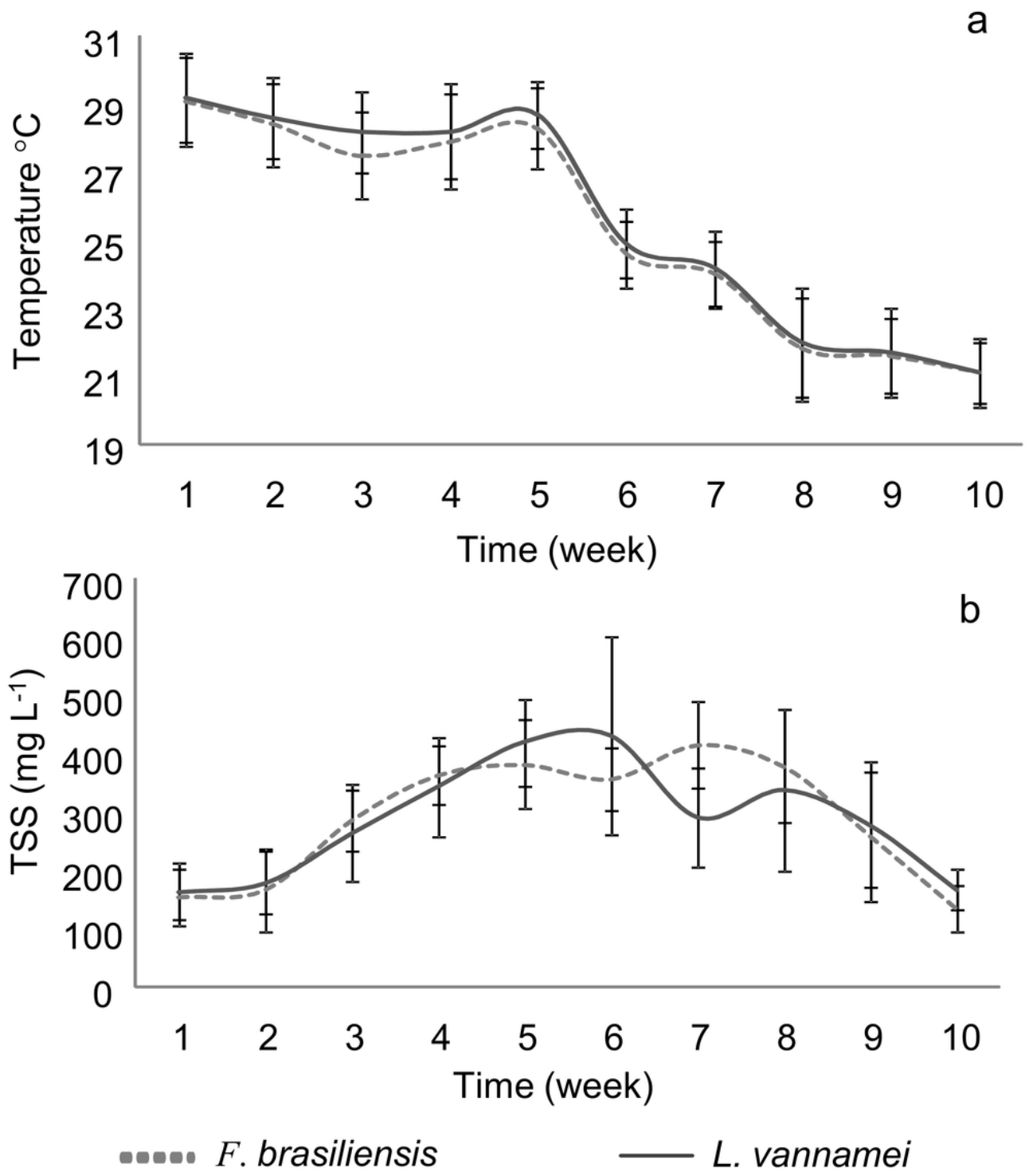

Figure 2

Variations (means ± standard deviation) of (a) temperature, (b) total suspended solids concentration during the culture of Litopenaeus vannamei and Farfantepenaeus brasiliensis in a biofloc system

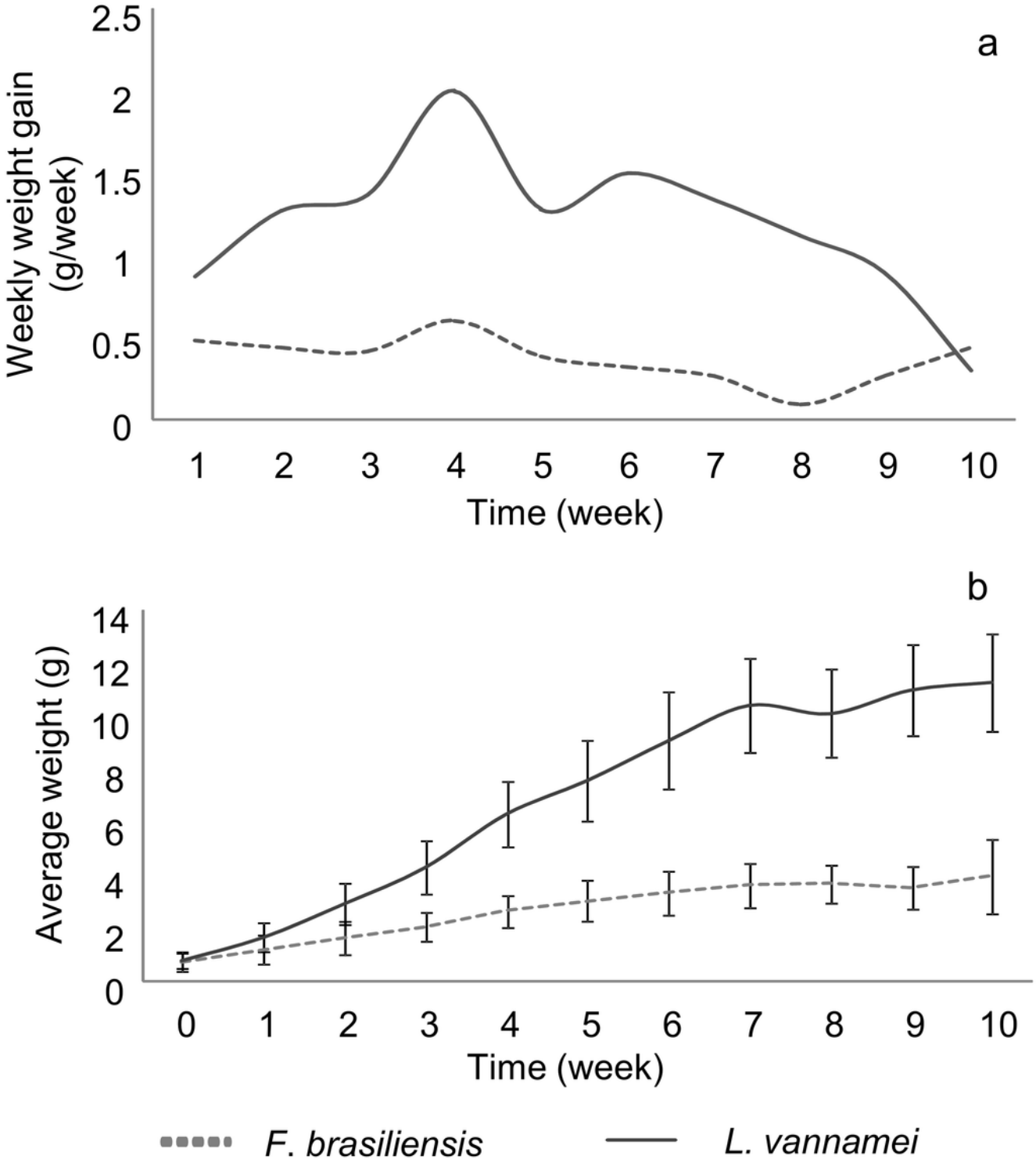

Figure 3

Mean values (means ± standard deviation) of zootechnical performance (a) weekly weight gain and (b) mean weight during the culture of Litopenaeus vannamei and Farfantepenaeus brasiliensis in a biofloc system

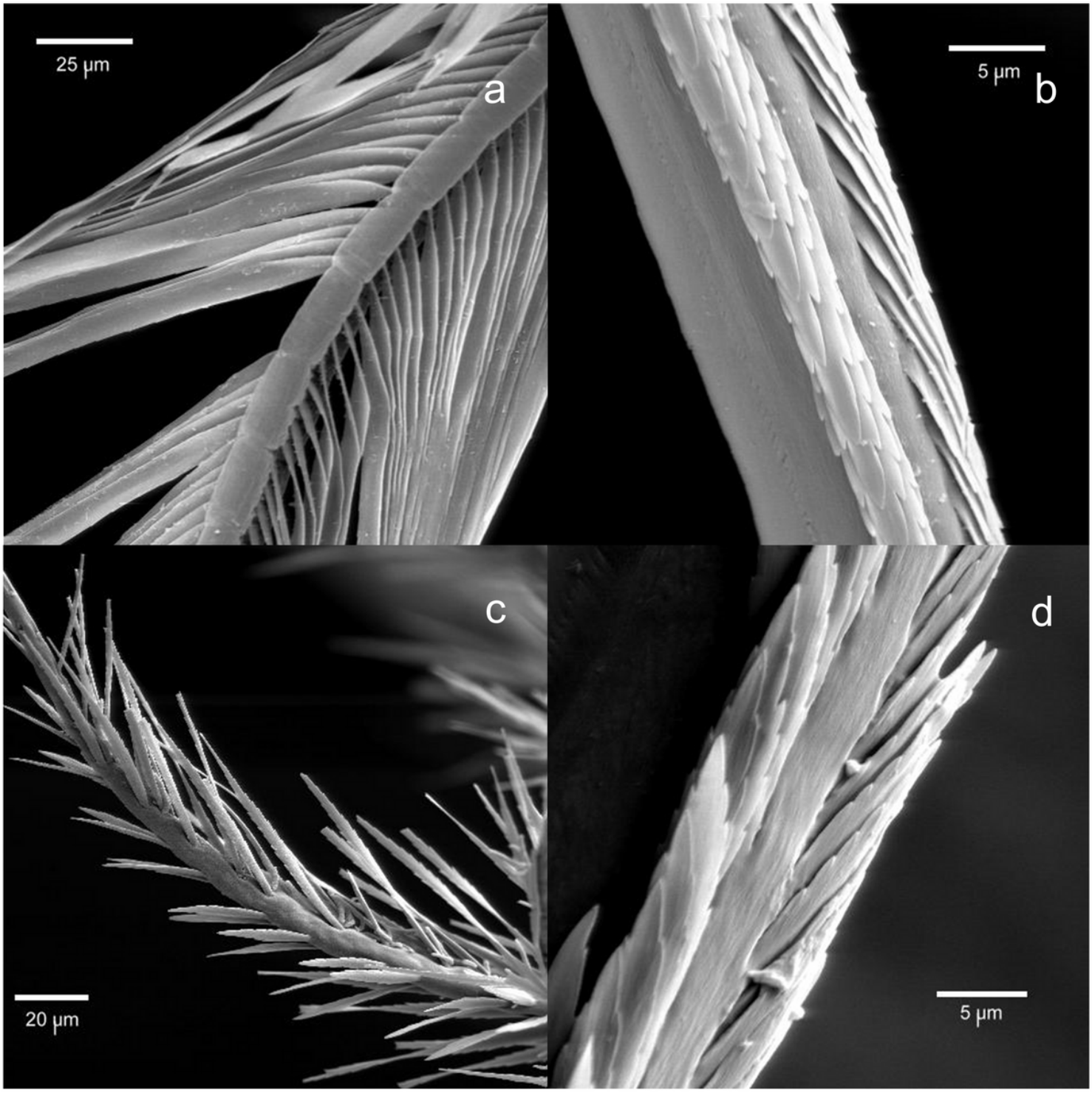

Figure 4

Scanning electron microscopy photographs of the third maxilliped (a) Litopenaeus vannamei 575x magnification (b) Litopenaeus vannamei 3000x magnification (c) Farfantepenaeus brasiliensis 600x magnification (d) Farfantepenaeus brasiliensis 3000x magnification cultured in biofloc system