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Nannochloropsis spp. as Feed Additive for the Pacific White Shrimp: Effect on Midgut Microbiology, Thermal Shock Resistance and Immunology

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Simple Summary: We evaluated *Nannochloropsis* spp. as a feed additive for the Pacific white shrimp by testing for thermal shock resistance, immunology, and midgut microbiology. *Nannochloropsis* spp. are rich in Eicosapentaenoic acid, an n-3 fatty acid. This study demonstrated that the inclusion of these microalgae in the diet increased shrimp resistance to thermal shock and stimulated shrimp immune defense.



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Abstract: This work aimed to evaluate *Nannochloropsis* spp. as feed additive in the diet of Pacific white shrimp for their effect on midgut microbiology, thermal shock resistance and immunological parameters. Initially, the digestibility of the microalgae meal was assessed, and the apparent digestibility coefficient (ADC) was determined. The ADC was, in general, high in lipids (78.88%) and eicosapentaenoic fatty acid (73.86%). Then, *Nannochloropsis* spp. were included in diets at four levels (0, 0.5, 1 and 2% inclusion). The shrimp were reared in 500 L clear water tanks containing 20 shrimp per tank with an initial weight of 6.05 ± 0.06 g and fed four times a day. Shrimp fed with supplemented diets containing *Nannochloropsis* spp. (0.5 and 2%) presented higher resistance to thermal shock when compared to the non-supplemented group (control). Shrimp fed with 1 and 2% of algae inclusion had a higher production of reactive oxygen species (ROS) when compared to other treatments. No statistical difference was observed in the immunological parameters and microbiology of the intestinal tract. Thus, the inclusion of *Nannochloropsis* spp. in shrimp diets at 0.5 and 2% levels increases resistance to thermal shock and ROS production in shrimp.

Keywords: *Litopenaeus vannamei*; EPA; low temperature thermal shock; immunological parameters; reactive oxygen species

1. Introduction

During the past few years, worldwide shrimp production has encountered limited development and production owing to, among other factors, viral and bacterial outbreaks [1]. Many methods have been used to treat or prevent the development of new diseases, such as chemical and antibiotic compounds. However, the harmful potential effect of synthetic drugs on animals and the environment made these compounds problematic. Thus, to avoid their use, alternative methods have been studied, for instance, good handling practices of production and the enhancement of the immunological resistance of shrimps. The balance among host, pathogen and the environment is crucial for the animals that, even though



Occupational risk perception in mollusk farm workers

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ABSTRACT

Marine bivalve mollusk farming in Santa Catarina, located in South Brazil is a noteworthy productive activity that generates jobs and income. However, workers in this sector are exposed to several workplace risks due to lack of security and occupational health policies. In order to contribute to the generation of knowledge in the sector, this study evaluated oyster and mussel farm worker occupational risk perception in Florianópolis, Brazil. An ergonomic analysis and the application of a semi-structured interview ($n = 38$) were carried out, as well as observation of the work environment. Results indicate that most of the participants are men with low educational level and that the most common accidents are cuts, shocks and falls. In addition, reports of muscle pain and allergies were also noted. The interviewees displayed ignorance regarding the occupational risks present at cultivation farms, and were also shown to underestimate accidents suffered during task execution. The data obtained herein indicate the need for the development of risk management policies, specific for marine bivalve mollusk farming, especially regarding worker education and organization work measures in mariculture.

1. Introduction

Shellfish farming is an important economic activity in many countries, with a worldwide production of 16 million tons in 2014 and an income of over 20 billion dollars. The main producing countries are China, Japan and South Korea (FAO, 2016). In Brazil, the state of Santa Catarina is responsible for over 90% of production in the form of marine mollusk farming, especially the mussel *Perna perna* and oyster *Crassostrea gigas* (dos Santos and Costa, 2016). The predominant farming system comprises long-line type floating (Novaes et al., 2014). Most producers sell *in natura* shellfish and farming time ranges from 7 to 10 months (Marenzi et al., 2008; Rupp et al., 2008).

Mollusk farming in Santa Catarina was driven by the Federal University of Santa Catarina and an agricultural extension agency (Epagri), in conjunction with artisanal fishermen (Borghetti and Silva, 2007). A decisive factor at the development of this sector was low financial investment, with the use of materials from other activities, allowing for the insertion of the low-income population (Marenzi et al., 2008). Currently, the activity generates jobs and income, contributing to the

establishment of traditional communities in the coastal area, directly and indirectly involving over 5,000 people (Suplicy et al., 2015). A total of 572 mariculturists live in Santa Catarina, producing 20,438 tons of shellfish (dos Santos and Costa, 2016). According to the Brazilian Federal Government the goal is to increase national production to 50,000 tons by 2020, which should attract investments and contribute to the generation of further employment in the sector (PDA, 2015). However, in order to expand this activity in a sustainable way, in addition to economic viability, both environmental and social aspects, as well as their risk factors, must be considered.

Among the main aquaculture-related dangers, occupational and environmental risks, food safety and public health are the most noteworthy (Erundu and Anyanwu, 2005; Watterson et al., 2012). Occupational risks can be classified as physical, chemical, biological, accidents, psychosocial and ergonomic (Brazil, 2015; WHO, 2007). Several of these risks, such as musculoskeletal disorders, electric shocks, solar radiation, allergies and falls, have been identified in oyster (Guertler et al., 2016), mussels (Stefani et al., 2011; Novaes et al., 2017), macroalgae (Fröcklin et al., 2012) and fish (Durborow et al., 2011; Myers, 2010; Phu et al.,

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Aquaponic production of sea asparagus and Pacific white shrimp using biofloc technology: Different irrigation regimes affect plant production of bioactive compounds and antioxidant capacity

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Abstract

This study aimed to evaluate the production of phenolic compounds, antioxidant activity and growth performance of *Sarcocornia ambigua* exposed to different periods of continuous irrigation in an aquaponics system with *Litopenaeus vannamei* reared in a biofloc technology (BFT) system, in addition to possible effects on shrimp growth performance, nitrogen recovery and water quality. Four treatments were evaluated as follows: 6, 12, 18 and 24 h of continuous irrigation per day, all set up in triplicate. Plants from the 12 and 24 h of irrigation treatments exhibited significantly higher values of phenolic compounds, 48.4 ± 1.8 and 47.7 ± 1.6 mg Gallic acid equivalent (GAE) 100 g^{-1} FW (fresh weight), respectively, when compared with the 6 and 18 h treatments, 42.6 ± 1.1 and 42.6 ± 1.3 mg GAE 100 g^{-1} FW, respectively ($p < 0.05$). Antioxidant activity also differed significantly between treatments ($p < 0.05$). The highest concentrations were found in treatments of 12 and 24 h of irrigation, which presented 41.3 ± 0.6 and 42.7 ± 0.8 μmol Trolox Equivalent Antioxidant Capacity (TEAC) 100 g^{-1} FW, respectively. For treatments of 6 and 18 h of irrigation, the concentrations were 29.9 ± 0.8 and 31.1 ± 1.5 μmol TEAC 100 g^{-1} FW. No significant differences between treatments were observed for plant and shrimp growth performance ($p \geq 0.05$). There was also no significant effect of the different irrigation periods on water quality ($p \geq 0.05$). The overall mean nitrogen recovery was 29.3% for all treatments. In conclusion, *S. ambigua* cultivated under 12 and 24 h of continuous irrigation exhibited higher production of bioactive compounds and antioxidant activity.

KEYWORDS

BFT, functional food, integrated culture, *Litopenaeus vannamei*, *Sarcocornia ambigua*, total phenolics

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Brown seaweeds added in the diet improved the response to thermal shock and reduced *Vibrio* spp. in pacific white shrimp post-larvae reared in a biofloc system

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Abstract

This work aimed to evaluate the effect of the combined use of the brown seaweeds *Sargassum filipendula* (S) and *Undaria pinnatifida* (U) dry biomass, as a feed additive, on growth performance, bacterial count and thermal shock resistance of Pacific white shrimp reared in a biofloc system during the nursery phase. Four combinations of seaweeds were evaluated: 0.5S:2U, 0.5S:4U, 1S:2U and 1S:4U (%), and a control diet. Shrimp post-larvae (PLs, initial weight ± 0.006 g) were reared for 7 weeks in 400 L polyethylene tanks, partially filled with water from a biofloc matrix tank, at density of 3000 PLs m⁻³, and were fed 6 times a day until reaching ± 1 g. The presence of Vibrionaceae in PLs was significantly lower in those that were fed diets containing 0.5S:4U and 1S:4U. For thermal shock resistance (from 29°C to 13.5 $\pm$ 0.1°C for 1 h, and returned to 29°C), PLs fed the diet containing 1S:2U showed lower cumulative mortality than those fed the other diets. Among all treatments, no significant difference was observed in growth performance and total heterotrophic bacteria count in the PLs. *S. filipendula* and *U. pinnatifida* showed a combined effect on shrimp thermal resistance and reduction of *Vibrio* spp. in PLs.

KEYWORDS

bacterial count, *Litopenaeus vannamei*, *Sargassum filipendula*, thermal resistance, *Undaria pinnatifida*

1 | INTRODUCTION

The biofloc system can be considered one of the most innovative and sustainable systems currently used in shrimp farming (Kumar et al., 2018). This system is based on the assimilation of inorganic nitrogen (ammonia, nitrite and nitrate) by the microbial community and the formation of agglomerates, called bioflocs, consisting of microalgae, protozoa, bacteria, yeast and organic and inorganic debris (Avnimelech, 2014; De Schryver et al., 2008).

Despite many positive characteristics, the biofloc system also has some disadvantages. It requires skilled labour to manage the system,

as it contains a high concentration of organic matter in the water, and it works with elevated stocking densities. Physicochemical imbalances within the system can lead to negative consequences, such as the proliferation of pathogenic bacteria. High concentrations of *Vibrio* spp. in the rearing water have been associated with shrimp mortality in biofloc systems (Krummenauer et al., 2014). Thus, even though the biofloc system is efficient in controlling water quality, management of the microbial community in the rearing water still requires further study.

However, this system has been successfully applied to virtually all phases of marine shrimp farming: hatchery, pre-nursery, nursery, grow-out and brood stock (Baloi et al., 2013; Lorenzo et al.,



Brown seaweeds as a feed additive for *Litopenaeus vannamei* reared in a biofloc system improved resistance to thermal stress and white spot disease

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Abstract

This study evaluated the combined use of the brown seaweeds *Sargassum filipendula* (S) and *Undaria pinnatifida* (U) dry biomass as feed additive for Pacific white shrimp reared in biofloc system, and its effect on shrimp performance, gut microbiota, hemato-immunological parameters, resistance to acute thermal stress and challenge with White Spot Syndrome Virus (WSSV) associated with thermal fluctuation. Prior to stocking, it filled each tank with water from a biofloc matrix tank (160 L) + seawater (240 L, salinity: 33 g L⁻¹), then stocked with 300 shrimp m⁻³ (~3.8 g). During the experiment (five weeks), shrimp were fed three diets: without (control) and with 1%:2% and 1%:4% (S:U) of seaweed addition (all in quadruplicate); and alkalinity was maintained above 150 mg L⁻¹ with calcium hydroxide and solids between 400–600 mg L⁻¹ using clarifiers. No significant differences were found in survival, feed conversion ratio, and growth among treatments. Shrimp from 1S:2U treatment showed the highest gut bacterial diversity. Additionally, animals from seaweed-fed treatments, especially 1S:2U, displayed lower abundance of Vibrionaceae and higher of Flavobacteriaceae compared to control. Only shrimp from 1S:4U treatment showed higher hemato-immunological parameters (except total hemocyte count) than control. Animals from 1S:2U had lower cumulative mortality (27%) than 1S: 4U (48%) and control (50%) after acute thermal stress. Meanwhile, shrimp from 1S:2U (26%) and 1S:2U (34%) showed lower cumulative mortality after WSSV challenge + thermal fluctuation than control (68%). Therefore, the dietary addition of both brown seaweeds caused beneficial physiological effects for *L. vannamei* without impairing its performance.

Keywords Marine shrimp · *Sargassum filipendula* · *Undaria pinnatifida* · Thermal shock · WSSV · Growth

Introduction

The intensification process of marine shrimp production systems, over the last decades, has led to a significant increase in the productivity of cultivation farms. However, the increase in stocking densities and feed input into production systems has also resulted in a corresponding increase in the discharge of nitrogen and other potential pollutants

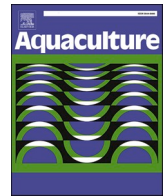
into aquatic environments, besides increasing the potential spread of diseases (Boyd 2003; Piedrahita 2013).

However, biofloc technology (BFT) has reduced risks arising from the intensification of production since it is based on the recycling of nutrients and low water renewal (Emerenciano et al. 2013; Bossier and Ekasari 2017). In this system, the reuse of crop water in multiple production cycles has been proven effective, preventing the occurrence of excess nitrogen compounds. This can be attributed to preservation of the complex bacterial communities that establish during the first production cycles. Commonly known as a mature system, this primary inoculum is used for tanks starting their production cycle (Krummenauer et al. 2014). Ferreira et al. (2021), have analyzed the three phases of a biofloc system, including heterotrophic, chemoautotrophic and mature. When in the chemoautotrophic and mature phases, they observed that the biofloc system was suitable for the cultivation of marine shrimp. However, management is still

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Hemato-immunological parameters can be influenced by microalgae addition and fish feed supplementation in the integrated rearing of Pacific white shrimp and juvenile Nile tilapia using biofloc technology

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ABSTRACT

This study evaluated the effects of microalgae (*Scenedesmus obliquus*) addition and fish feed supplementation on hemato-immunological parameters of Pacific white shrimp (*Penaeus vannamei*) and juvenile Nile tilapia (*Oreochromis niloticus*) cultured in integration using biofloc technology for 62 days. The experiment was designed as a factorial design with two factors, totaling four experimental groups: (1) No addition of microalgae and no addition of fish feed; (2) no addition of microalgae and addition of fish feed; (3) addition of microalgae and no addition of fish feed; and (4) addition of microalgae and addition of fish feed. In all groups shrimp were fed according to a feeding table. Shrimp (2.16 ± 0.01 g) and fish (1.53 ± 0.12 g) were cultured under densities of 400 shrimp m^{-3} and 522 fish m^{-3} in 800 L and 90 L (useful volumes) tanks maintained under water recirculation. Microalgae was added two times a week for a final concentration of 5 $mg\ L^{-1}$ in the units, while a commercial fish feed was provided at the rate of 1% of the fish biomass daily. At the end of the trial, the fish and shrimp were sampled for the hemato-immunological analyses. As regards the shrimp, there was a significant effect of the interaction on total hemocyte count ($p < 0.05$), in which the highest value occurred in the group with microalgae/no fish feed addition. There was also a significant effect of microalgae addition on serum protein ($p < 0.05$), with the highest values occurring in the treatments that employed microalgae. In the case of the fish, the monocyte count was significantly affected by the fish feed addition ($p < 0.05$), the highest values being observed when the feed was provided. There were also significant effects of the interaction and of microalgae addition on mean corpuscular volume and mean corpuscular hemoglobin concentration ($p < 0.05$), with the highest values occurring in the group that received microalgae but no fish feed and in the groups that did not receive microalgae, respectively. Overall, these results suggest an enhanced immunological status for the shrimp due to increases in total hemocyte count and high serum protein concentration when microalgae was added and an improved nutritional status for the fish that received feed due to increased circulating monocytes, along with possible greater erythrocyte stability when microalgae was added.

1. Introduction

Global aquaculture production has been increasing in the past few decades both in terms of absolute value and in its share in the overall production of aquatic organisms. This can be attributed to worldwide population growth, greater demand for high quality animal protein and a stagnant capture fisheries sector (FAO (Food and Agriculture Organization of the United Nations), 2022). For instance, in 1990 the

production of aquatic animals was 110.7 million tons, of which 21.8 million tons (20%) were cultured. Thirty years later, aquaculture production increased fourfold to 87.5 million tons, corresponding to 49% of the total, with most of this growth being destined to human consumption.

In terms of species used worldwide, Pacific white shrimp [*Penaeus* (*Litopenaeus*) *vannamei*] is the main cultured crustacean, whereas Nile tilapia (*Oreochromis niloticus*) occupies the third position in the rank of

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Increased resistance to thermal shock in pacific white shrimp fed on green algae and its effect in conjunction with probiotics

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Abstract This study aimed to evaluate the *in vivo* effect of the macroalgae *Ulva ohnoi*, alone and combined with the probiotic *Lactobacillus plantarum*, on zootechnical, immunological, and microbiological performance, thermal resistance and survival of *Litopenaeus vannamei* challenged with *Vibrio parahaemolyticus*. The shrimp were fed four diets: control, seaweed, probiotic, and a combination of seaweed + probiotic. After six weeks, a significant difference between the control and probiotic, and the control and seaweed treatments was demonstrated in shrimp challenged with *Vibrio*, with the highest percentage of mortality being observed in the group fed only with seaweed, followed by probiotic, seaweed + probiotic, and control. The control and seaweed treatment groups also showed a significant difference in resistance to thermal shock. The animals treated with the control diet had the highest mortality rate, followed by seaweed + probiotic, probiotic, and seaweed. The zootechnical, immunological, and microbiological parameters did not differ significantly among treatments. In conclusion, the use of *U. ohnoi* alone demonstrated a positive effect on thermal shock resistance but did not demonstrate protection against infection caused by *V. parahaemolyticus*. On the other hand, its combined use with *L. plantarum* in the diets did not have a positive effect on the parameters evaluated.

Keywords *Litopenaeus vannamei* . *Ulva ohnoi* . *Lactobacillus plantarum* . *Vibrio* . Thermal shock

Introduction

The pacific white shrimp (*Litopenaeus vannamei*) is considered one of the most important species for shrimp farming and in recent years, production has increased significantly. Marine shrimp are ectothermic organisms that can be stressed due to temperature fluctuations in their culture system. At low temperatures, general metabolic functions such as the immune, antioxidant, and osmoregulation systems, and the behavior and growth of these animals, can be negatively affected (Xu et al. 2019; Ren et al. 2021).

In addition, changes in environmental factors contribute to the immunosuppression of cultured animals and may increase their susceptibility to diseases caused by pathogenic viruses and bacteria (Reverter et al. 2014; Klongklaew et al. 2020; Jiao et al. 2021). Among the infections are those caused by bacteria of the genus *Vibrio*, such as *Vibrio parahaemolyticus*, known to be the etiologic agent of acute hepatopancreatic necrosis disease (AHND) that has caused enormous economic losses in global shrimp farming (Boyd and Phu 2018; Santos et al. 2020).

One of the strategies employed to control these microbial infections in farmed animals is the use of antibiotics. However, their indiscriminate use is not recommended, since they can accumulate in the tissues of

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and in proteins related to microbial defenses. Furthermore, Legarda et al. (2021) when supplementing with *U. fasciata* (10 g kg⁻¹) in the diet of yellowtail amberjack (*Seriola Dorsalis*) found an increase of approximately 49% in docosahexaenoic acid (DHA) in fish muscle tissue. Based on these studies, it is suggested that the increase in unsaturated fatty acids may be due to their incorporation into the cell membrane, thus increasing its fluidity and this could explain, in part, the greater resistance to thermal shock in animals fed diets supplemented with algae.

Seaweeds, when included at low levels in the diet, can behave as immunostimulant sources and improve the immune response of animals. This has also been demonstrated with the use of probiotics (Vidhya Hindu et al. 2019). However, when evaluating the survival of shrimp fed supplemented diets and challenged with *Vibrio parahaemolyticus*, a negative effect on their resistance was observed. Even the animals fed the diet containing only *U. ohnoi* had the highest mortality rate, demonstrating a significant difference from the control group. In addition, the animals supplemented with probiotics showed a higher mortality rate when compared to the control group. In contrast to these results, Akbary and Aminikhoei (2018) observed that the use of *U. rigida* extract in *L. vannamei* diets improved animal resistance after bacterial challenge with *Photobacterium damsela*, and the same was verified in red seabream (*Pagrus major*) fed with *Ulva pertusa* and infected with *Photobacterium damsela* subsp. Piscicide (Sato et al. 1987). Results divergent from those obtained in the present study were also reported by several studies in which the use of *Lactobacillus* sp. increased the resistance of shrimp when challenged with *V. harveyi* (Vieira et al. 2010; Kongnum and Hongpattarakere 2012; Li et al. 2018). One explanation for these contradictory results is that probiotics are influenced by factors such as culture conditions, the method of administration and concentration, the probiotic strain, and the species of fish or shrimp used (Toledo et al. 2019). In relation to experiments using algae, some authors, such as Fumanal et al. (2020), demonstrated that the proportion of algae can influence the final result, and it is necessary to test its specific effects for each species of animal and diet formulation, always considering that its compounds may vary in different species of algae (Martínez-Antequera et al. 2021). Furthermore, the results obtained in the present study suggest that the inoculum of *V. parahaemolyticus*, used at a concentration of 3×10^8 CFU mL⁻¹ (obtained in a previous LD50 test), may have been very high, and the control group reached 65% mortality, slightly above the expected 50%.

The addition of 2% dry seaweed biomass alone and together with the probiotic in the diets did not show significant differences in the counts of intestinal tract bacteria, such as lactic acid bacteria (LAB), which indicates that there was no colonization of these bacteria in the intestines of shrimps, the expected prebiotic effect not occurring. There were also no statistical differences in the evaluated immunological parameters, which is consistent with findings of other studies (Fumanal et al. 2020). In addition, the zootechnical parameters of the animals fed the supplemented diets were not affected, suggesting that there was no interference from possible anti-nutritional factors present in the algae, as demonstrated in other studies (Bandara 2018; Vizcaíno et al. 2019, 2020; Sáez et al. 2020).

Although several studies demonstrate that seaweed and probiotics have many benefits for the health of farmed animals, there are divergences in the results found in the literature. These differences may be due to the variation of the farmed species and its physiology, the macroalgae and the probiotic strain used, the method of inclusion, the dosage administered, the place and season of the year in which the algae were harvested, and the form of drying them (Vatsos and Rebours 2015; Araújo et al. 2016; Uribe et al. 2019; Vizcaíno et al. 2019). Consequently, the results obtained in the present study reveal the importance of evaluating the effects of the use of different species of *Ulva* in shrimp feeding and their combination with probiotics. To our knowledge, this is the first report on the inclusion of *U. ohnoi* alone and together with *L. plantarum* in *L. vannamei* diets.

Conclusion

The inclusion of *U. ohnoi* in the diet of *L. vannamei* demonstrated a positive effect on resistance to thermal shock but did not demonstrate protection against infection caused by *V. parahaemolyticus*. The use of this macroalgae together with *L. plantarum* in the diets did not exert any synergistic or antagonistic effect on the zootechnical, immunological, and microbiological performance of the animals.

Conflict of interest The authors have no competing interests to declare.



Authors' contributions All authors have contributed equally to data collection, data analysis, writing, reviewing, editing, and finally, approving the final manuscript.

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Article

Nematodes Can Substitute *Artemia* in a Co-Feeding Regime for Pacific White Shrimp Post-Larvae Reared in a Biofloc Nursery System

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Simple Summary: The use of *Artemia* as a supplement to commercial feed during the nursery period, i.e., from post-larvae 10 up to post-larvae 30, is a common procedure in the shrimp industry. This practice provides larger and more resilient post-larvae (PL) that perform better in grow-out ponds. However, the production of brine shrimp is limited to a few natural salt lakes or man-made salt ponds worldwide, subject to strongly fluctuating yields and product quality. Therefore, ongoing research is focused on finding adequate live food alternatives. Nematodes, commonly known as worms, are animals that greatly fulfil the requirements to be used as live feed for aquatic organisms. Nematodes can be reactivated from their desiccated state by simple rehydration. Additionally, they are rich in protein and fatty acids, making them a favorable nutritional diet for shrimp larvae culture. This study demonstrated that nematodes can substitute *Artemia* in a co-feeding regime for the nursery of shrimp in a biofloc system, increasing the survival of the post-larvae after 20 days.



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Abstract: This study evaluated nematodes as an alternative to live *Artemia* when provided in a co-feeding regime to Pacific white shrimp (*Penaeus vannamei*) post-larvae (PL) reared in a biofloc nursery system. A 20-day experiment employing PL₁₁ was performed for an evaluation of four dietary groups: control [C] (fed exclusively with a dry commercial feed); artificial *Artemia* [AA] (dry feed composed of extracted and processed *Artemia* cysts and dry commercial feed); live *Artemia* and dry commercial feed [LA]; and nematodes and dry commercial feed [N] (*Panagrolaimus* sp. dry nematodes). The diets were provided twice a day, with the remaining six feed provisions being a commercial dry feed for all experimental groups. A biofloc system was chosen as it offers a potentially sustainable approach to intensive shrimp farming. Alkalinity and pH in the [N] group were significantly higher in the last 5 days of the experiment ($p < 0.05$), likely causing the significantly lower nitrite levels observed in that same group ($p < 0.05$). Total and volatile suspended solids were significantly lower in the two live feed groups when compared with [C] and [AA] ($p < 0.05$). Although PL fed the dry diets exhibited higher growth rates ($p < 0.05$), the [N] and [LA] groups presented significantly higher final survivals ($p < 0.05$). No differences were found for survival after a salinity stress test ($p \geq 0.05$). These results suggest that nematodes can successfully substitute *Artemia* in a co-feeding regime for *P. vannamei* PL reared in biofloc nursery systems.

Keywords: live feed; *Penaeus vannamei*; brine shrimp; Nematoda; larval nutrition; BFT