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B Gunalan
Department of Zoology, Presidency College (Autonomous), Chennai, Tamil Nadu, India

Vijay Kumar BS
Centre of Advanced Study Marine Biology, Faculty of Marine Sciences, Annamalai University, Parangipettai, Tamil Nadu, India

Mansingh VR
Centre of Advanced Study Marine Biology, Faculty of Marine Sciences, Annamalai University, Parangipettai, Tamil Nadu, India

Sankar G
Department of Zoology, Government Arts College for Women (Autonomous), Pudukkottai, Tamil Nadu, India

Nithya Mary G
PG & Research, Department of Zoology, Kanchi Mamunivar Government Institute for Postgraduate Studies and Research, Lawspet, Puducherry, India

Corresponding Author:
B Gunalan
Department of Zoology, Presidency College (Autonomous), Chennai, Tamil Nadu, India

Analysis of growth in high saline nursery and grow-out culture of *Litopenaeus vannamei* on the southeast coast of India

B Gunalan, Vijay Kumar BS, Mansingh VR, Sankar G and Nithya Mary G

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Abstract
This study presents a comprehensive analysis of the nursery and grow-out phases in the aquaculture of Pacific white shrimp (*Litopenaeus vannamei*). In the nursery tank, a constant salinity of 43 ppt was maintained, alongside pH fluctuations (7.7-8.2), dissolved oxygen levels (6.5-7.5 ppm), alkalinity variations (140-200 ppm), and ammonia concentrations (0.1-0.2 ppm). Microbial populations exhibited 300-500 yellow colonies (cfu/ml) and 60-80 green colonies (cfu/ml). Shrimps, stocked at 6.7 pieces per litre, demonstrated impressive growth, reaching an average body weight of 0.90 grams, with a daily gain of 0.031 grams and a survival rate of 87%.The transition to grow-out ponds featured diverse stocking densities (10-17 m^2) and salinity levels (45-48 ppt). Water quality parameters, including hydrogen ion concentration (7.9-8.5), dissolved oxygen (4-4.5 ppm), ammonia (0.1 ppm), alkalinity (100-120 ppm), magnesium (1000 ppm), and calcium (900 ppm), were carefully managed. Beneficial bacteria ranged from 300 to 700 cfu/ml, while harmful bacteria varied from 40 to 120 ppm. Survival rates were highest in Ponds 1C, 1D, and 1E (80-90%), with a feed conversion ratio (FCR) of 1.4 in Pond 1E and 1.5 in others. Peak daily growth occurred in Ponds 1B, 1D, and 1E at 0.4 grams, with the greatest growth of 33 grams observed in Ponds 1D and 1E. Pond 1A yielded the highest harvest quantity at 1640 kg, accompanied by the highest feed usage at 2500 kg. This study underscores the significance of effective water quality management in optimizing growth and survival in Pacific white shrimp aquaculture.

Keywords: High saline, nursery culture, shrimp, *Litopenaeus vannamei*, growth, grow out ponds, water quality

Introduction

Litopenaeus vannamei (Boone, 1931) stands as the most crucial species in global crustacean aquaculture. The cultivation of white leg shrimp, *Litopenaeus vannamei*, has witnessed remarkable expansion, achieving a production milestone of 4,966,200 MT as of 2020 [1, 2]. Over the past three years, this production has experienced consistent growth at a compound annual rate of 5.7% [3]. However, the industry faces pressing challenges, including environmental degradation, climate change, and the proliferation of pathogens, all of which hamper the sustainable development of white leg shrimp farming worldwide [4]. Moreover, white leg shrimp producers grapple with challenges arising from fluctuating international market prices, feed and fuel costs, as well as the persistence of white leg shrimp diseases [3].

To achieve improved growth, it is essential to have disease-free post-larvae, as well as modern hatcheries equipped with proper sanitation, quality control, automation, water recycling, and a reduction in the reliance on fresh food [4].

As is the case with many industries, the productivity of white leg shrimp producers plays a pivotal role in determining their profitability. For over two decades, a two-phase system, comprising a nursery stage followed by a grow-out stage, has been implemented to enhance the quality of white leg shrimp production in super-intensive settings [5]. Within the realm of intensifying white leg shrimp production, the density of the shrimp population emerges as a critical factor. Under high-density conditions, various physico-chemical variables and population parameters, such as the specific growth rate (SGR) and survival rate, assume paramount importance. It is crucial to underscore that the effective management of post larvae during the nursery phase exerts a significant influence on their growth and survival, forming the cornerstone for achieving optimal growth performance in the subsequent grow-out phase [6]. Nursery systems in the white leg shrimp farming industry offer numerous advantages, including enhanced inventory control, improved size uniformity, decreased predation risks, shortened pond grow-out periods, increased harvest frequency, enhanced feed conversion efficiency, and heightened biosecurity [7, 8]. Therefore, the focus of the present study is to assess the impact of high saline conditions on both nursery culture and grow-out ponds.

Materials and Methods

The experimental research was conducted at Raj Kumar Aqua Farm in PR Puram, Vailankanni, Tamil Nadu. The concrete nursery tank had a capacity of 75 MT, and there were five grow out ponds: 1A (0.5ha), 1B (0.5ha), 1C (0.4ha), 1D (0.3 ha), and 1E (0.3 ha). Specific pathogen-free and resistance L. vannamei seeds were procured from a hatchery approved by the Coastal Aquaculture Authority. The seeds were carefully transported in double-layered polythene bags with crushed ice packs, maintaining oxygenation. Upon arrival, they were acclimatized in a one-ton capacity fibre tank, adjusting salinity using water from the nursery tank. The seeds were released after ensuring the water quality parameters matched those of the nursery tank, following the method described by [9].

In the nursery tank, water exchange occurred twice daily (50%), and aggressive aeration was provided to maintain optimal dissolved oxygen levels. Water quality parameters were monitored and adjusted twice daily, ensuring proper salinity, temperature, and pH levels. Probiotics were administered every three days once.

Feeding program for one lakh post larvae

"Starting from the first day with 200 grams, there is an increase of 120 grams in the daily feeding amount until the seventh day. From the eighth day to the fourteenth day, the daily increment remains at 200 grams, and from the fifteenth day to the thirtieth day, there is a daily increment of 300 grams. Feeding occurs eight times per day with an equal distribution up to the thirteenth day, and from the fourteenth day onwards, feeding happens six times per day, starting at 6 am in the morning."

Table 1: Shows the feeding schedule for first 14 days

Doc	Feed code	6AM	9AM	12PM	3PM	6PM	9PM	12AM	3AM	Total Feed	PCC Feed	Feed increase Lakh
1	N1	25	25	25	25	25	25	25	25	200	200	200
2	N1	40	40	40	40	40	40	40	40	320	520	120g
3	N1	55	55	55	55	55	55	55	55	440	960	120g
4	N1	70	70	70	70	70	70	70	70	560	1520	120g
5	N1	85	85	85	85	85	85	85	85	680	2200	120g
6	N1	100	100	100	100	100	100	100	100	800	3000	120g
7	N1	115	115	115	115	115	115	115	115	920	3920	120g
8	N1	140	140	140	140	140	140	140	140	1120	5040	200g
9	N1+N2	140+25	140+25	140+25	140+25	140+25	140+25	140+25	140+25	1320	6360	200g
10	N1+N2	95+95	95+95	95+95	95+95	95+95	95+95	95+95	95+95	1520	7880	200g
11	N2+N1	185+30	185+30	185+30	185+30	185+30	185+30	185+30	185+30	1720	9600	200g
12	N2	240	240	240	240	240	240	240	240	1920	11520	200g
13	N2	265	265	265	265	265	265	265	265	2120	13640	200g
14	N2	290	290	290	290	290	290	290	290	2320	15960	200g

Table 1a: Shows the feeding schedule for 14 to 30 days

Doc	Feed code	6:00 AM	9:00 AM	12:00 PM	3:00 PM	6:00 PM	9:00 PM	TotaI Feed	ACC Feed	Feed Increase Lakh
15	N2	340	340	340	340	340	340	2040	18000	303g
16	N2	390	390	390	390	390	390	2340	20340	303g
17	N2	440	440	440	440	440	440	2640	22980	303g
18	N2+N3	490	490	490	490	490	490	2940	25920	303g
19	N2	540	540	540	540	540	540	3240	29160	303g
20	N2	590	590	590	590	590	590	3540	32700	303g
21	N2	640	640	640	640	640	640	3840	36540	303g
22	N2	690	690	690	690	690	690	4140	40680	303g
23	N2+N3	740	740	740	740	740	740	4440	45120	303g
24	N2+N3	790	790	790	790	790	790	4740	49860	303g
25	N2+N3	840	840	840	840	840	840	5040	54900	303g
26	N2+N3+9002	890	890	890	890	890	890	5340	60240	303g
27	N2+N3+9002	940	940	940	940	940	940	5640	65880	30g
28	N3+9002	990	990	990	990	990	990	5940	71820	303g
29	N3+9002	1040	1040	1040	1040	1040	1040	6240	78060	303g
30	N3+9002+7702	1090	1090	1090	1090	1090	1090	6540	84600	303g

The grow-out ponds were prepared following the methods outlined by [10]. The water level was measured using a standard scale marked in centimetres. Various water quality parameters, including salinity, pH, temperature, dissolved oxygen, and light transparency, were measured using a hand refractometer, pH pen, thermometer, dissolved oxygen meter, and Secchi disc, respectively. Aeration was provided throughout the entire culture period for all ponds. Each culture pond was equipped with a total of six horsepower aerators strategically positioned to maximize the dissolution of oxygen into the pond water, ensuring an environmentally friendly culture environment. The Feed Conversion Ratio (FCR) and Average Daily Growth (ADG) were calculated using the formulas provided below.

FCR = Total weight of the harvested shrimps / total feed used
ADG = Total weight gained by the shrimps / Total days of culture

Results

The nursery tank maintained a consistent salinity of 43 ppt throughout the entire culture period. The pH levels fluctuated between 7.7 and 8.2, while the dissolved oxygen levels ranged from a maximum of 7.5 ppm to a minimum of 6.5 ppm. Alkalinity varied between 140 and 200 ppm, and the recorded ammonia levels fluctuated between a maximum of 0.2ppm and a minimum of 0.1 ppm. The magnesium concentration reached a peak at 1200 ppm, and the calcium level was recorded at a maximum of 900 ppm. The microbial population in the tank showed a range of 300 to 500 yellow colonies (cfu/ml) and 60 to 80 green colonies (cfu/ml) (Table: 2).

Table 2: Shows the average water quality parameters results in nursery tank

Parameters	Nursery tank
Salinity (ppt)	43
pH	7.7-8.2
Dissloved oxygen (ppm)	6.5-7.5
Alkalinity (ppm)	140-200
Ammonia (ppm)	.1-.2
Nitrite (ppm)	Nil
Mg (ppm)	900-1200
Ca (ppm)	600-900
Yellow colony (cfu/ml)	300-500
Green colony (cfu/ml)	60-80

In the nursery tank, shrimps were stocked at a density of 6.7 pieces per litre. The shrimps exhibited an average body weight of 0.90 grams. A daily weight gain of 0.031 grams was observed, with an impressive survival rate of 87%. The feed conversion ratio for the shrimps was calculated at 1.11 (Table: 3).

Table 3: Shows the Nursery tank culture details

Stocking Detail	Nursery Size (Mt)	75
	Stocking Date	10-04-2022
	Total Stocking (Pcs)	300000
	Density (Pcs/L)	6.7
Harvested Detail	Harvest Date	09-05-2022
	Shrimp Harvested (Kg)	235
	Feed Used (Kg)	260
Performance	DOC	29
	Size(ABW)	0.90
	ADG(Gr)	0.031
	Sur %	87
	FCR	1.11
	Salinity (PPT)	43

Effective water quality management in the nursery tank facilitated the growth of shrimps, with weights reaching.7 grams on the 29th day of culture (DOC), 1.0 gram on the 30th DOC, and 1.2 grams on the 31st DOC. Following their growth, the shrimp were transferred to grow-out ponds based on their size.

Table 4: Shows the average water quality parameters results in grow out culture ponds

Parameters	Grow out pond
Salinity (ppt)	45-48
pH	7.9-8.5
Dissloved oxygen (ppm)	4.0-4.5
Alkalinity (ppm)	100-120
Ammonia (ppm)	.1
Nitrite (ppm)	Nil
Mg (ppm)	600-1000
Ca (ppm)	500-900
Yellow colony (cfu/ml)	300-700
Green colony (cfu/ml)	40-120

In the grow-out ponds, 1A and 1B were stocked at a density of $10m^2$, pond 1C was stocked at $13m^2$, and ponds 1D and 1E were stocked at $17m^2$ each. The recorded salinity levels averaged between 45 ppt to 48 ppt, with the highest salinity of 48 ppt observed in ponds 1C and 1D. Hydrogen ion concentrations fell within the range of 7.9 to 8.5. Dissolved oxygen levels were consistently maintained between 4 ppm to 4.5 ppm. Ammonia levels were recorded at 0.1 ppm. Alkalinity levels, comprising both carbonate and bicarbonate, fluctuated between 100 ppm to 120 ppm. The maximum recorded magnesium level was 1000 ppm, while calcium levels reached 900 ppm. Beneficial bacteria levels ranged from 300 to 700 cfu / ml and harmful bacteria levels ranged from 40 to 120 ppm (Table: 4).

Survival rates in the grow-out pond were as follows: Pond 1C, 1D, and 1E had the highest survival at 90%, followed by 88% in 1A and 80% in 1B. The feed conversion ratio (FCR) was 1.4 in Pond 1E, while all other ponds had a 1.5 FCR. Daily growth reached its peak at 0.4 grams in Ponds 1B, 1D, and 1E, followed by 0.39 grams in Pond 1A and 0.37 grams in Pond 1C. The greatest growth, 33 grams, was observed in Ponds 1D and 1E, with Pond 1A close behind at 32.8 grams. In terms of harvest, Ponds 1D and 1E yielded the highest quantity at 1650 kg, followed by Pond 1A with 1640 kg. Pond 1A also had the highest feed usage at 2500 kg (Table: 5).

Table 5: Shows the grow out culture ponds details

	Pond No	1A	1B	1C	1D	1E
Stocking Detail	Pond Size(Ha)	0.5	0.5	0.4	0.3	0.3
	Stocking Date	9-05-22	9-05-22	10-05-22	11-05-22	11-05-22
	Total Stocking (Pcs)	50000	50000	50000	50000	50000
	Density (Pcs/Sq.m)	10	10	13	17	17
	Nuresry ABW (grm)	0.7	0.7	1.0	1.2	1.2
	Nuresry DOC	29	29	30	31	31
Harvested Detail	Harvest Date	01-08-22	27-07-22	26-06-22	29-07-22	29-07-22
	Shrimp Harvested (Kg)	1640.0	1280.0	1372.5	1650.0	1650.0
	Feed Used (Kg)	2500	1960	2000	2400	2350
Performance	DOC	84	79	81	81	81
	Size (ABW)	32.80	32.00	30.50	33.00	33.00
	ADG (Gr)	0.39	0.40	0.37	0.4	0.4
	Sur %	88	80	90	90	90
	FCR	1.5	1.5	1.5	1.5	1.4
	Salinity (PPT)	45	45	48	48	45

Discussion

Maintained [11] the salinity in the nursery tank at 32 to 33.5 ppt. The Present study recorded a salinity of 43 ppt. Growth ranging from 0.7 grams to 1.2 grams were observed at a density of 6.7 individuals per liter in the present study. Similar findings were reported by various authors, such as [12, 13]. These authors noted an inversely proportional relationship between the growth performance of *L. vannamei* and stocking density during the nursery phase. The decrease in growth with increased density in the nursery phase has been attributed to factors like diminished water quality, natural productivity, and space, as suggested by [14, 12, 13]. In the nursery phase, this parameter can have a wide distribution of size by weight up to 24.0%–70.0% of CV-BW [15, 6]. However, in the present study, no size variation was observed [16]. Reported minimal size variation and limited growth in their study using the bioflac nursery system.

The growth and survival parameters observed in CW-RAS, PT, and BFT systems fell within the range considered suitable for the nursery phase in intensive white leg shrimp farming, as indicated by previous studies [17, 18, 19]. In the present study per day two time water exchange was carried out reduce the ammonia problem and also the growth very good with any obstacles. Several authors have noted that during the nursery phase, the variability in the size of white leg shrimp can be attributed to size-dependent factors influencing growth, along with the potential impact of overcrowding on size heterogeneity [20, 21].

Recently [22] implemented a water-reusing biofloc system for Pacific white shrimp, aiming to maintain the requisite water quality for super-intensive cultivation in closed systems without the need for water renewal. This approach effectively managed solids without any connection to the sea, ensuring high biosecurity against external diseases in marine shrimp farms. However, in contrast, the current study opted for a different approach, conducting water exchanges twice daily to sustain optimal water quality and promote growth while addressing ammonia concerns. Various studies, including those by [23, 24, 25, 26] have reported comparable shrimp performance in reusing-water systems (RS) when compared to other nursery biofloc systems. Nevertheless, in the present study, parameters related to the growth performance of postlarvae in the nursery system, such as final body weight, specific growth rate, and productivity, was significantly superior in the clear water method.

On the contrary, [27] observed that the growth of shrimp juveniles was more favourable in the water-reused biofloc system compared to the control [25]. Documented that temperature, salinity, dissolved oxygen (DO), and pH in their study remained within acceptable ranges for the growth of *L. vannamei*. Similarly, the average results in the present study align with these findings. The decrease in dissolved oxygen (DO) observed over the culture period is likely attributed to the increased weight of the shrimp and the proliferation of bacterial populations in the cultured water. However, in the present study, the recorded dissolved oxygen levels ranged from a minimum of 4 ppm in the grow-out pond to a maximum of 7.5 ppm in the nursery tank [28]. Emphasized that a minimum DO standard of 3 mg/l is essential for ensuring the optimal growth, low feed conversion ratio, and high survival of shrimp [10]. Further supported this by reporting that dissolved oxygen levels between 4 to 7 ppm demonstrate favourable growth in the grow-out system.

In the current study, the environmental conditions in the grow-out ponds, including water temperature, salinity, dissolved oxygen, and pH, consistently fell within the optimal ranges for Pacific white shrimp culture, as established by [29, 9, 10]. The pH values obtained in the experiment, ranging from 7 to 9, align with the recommended range for optimal performance in the penaeid family, as noted by [29, 30]. Various reports have highlighted successful ammonia reduction in limited/zero-exchange culture systems through the manipulation of the carbon-to-nitrogen ratio, leading to the assimilation of inorganic nitrogen compounds and the production of microbial biomass [31, 32, 33, 34, 27]. In the present study, the lowest concentration of ammonia was consistently observed in all grow-out ponds, attributed to the maintenance of proper water quality and rigorous feed management, a finding supported by [35].

Reported [36] that nursery rearing of *L. vannamei* in Biofloc Systems (BFS) demonstrated beneficial effects across a wide salinity range, from 5 to 35 ppt, surpassing conventional water exchange systems. The average body weight showed a decreasing trend, while the survival rate increased with the rise in salinity. Notably, although the Average Body Weight (ABW) was higher at 5 ppt and the survival rate was higher at 35 ppt, the optimal combination of both ABW and survival rate was observed at 20 ppt salinity. Among the carbon sources tested, sugar exhibited promising results in the nursery rearing of *L. vannamei* seeds. In contrast, the present study's grow-out results indicate that a salinity range of 45 to 45 ppt led to 80% to 90% survival and 30 to 33 grams of growth. This suggests that proper water exchange and effective water quality management play a pivotal role in achieving better survival and growth, even under high salinity conditions in both nursery and grow-out phases.

References

1. FAO. The state of world fisheries and aquaculture - meeting the sustainable development goals. Licence: CC BY-NC-SA 3.0 IGO. Rome; c2018.
2. FAO. The State of World Fisheries and Aquaculture 2020. Sustainability in action. Rome; c2020.
3. Anderson JL, Valderrama D, Jory DE. Global shrimp production review. Global Aquaculture Advocate. 2019 Nov;(GOAL 2019):1-5. Available from: https://www.aquaculturealliance.
4. Jory DE. Around the world of shrimp: Notes from INFOFISH 2019. Global Aquaculture Advocate; c2019 Nov. p. 1-6. Available from: https://www.aquaculturealliance.org/advocate/around-the-world-of-shrimp-notes-from-infofish-2019/?headlessPrint=AAAAA.PIA9c8r7gs82oWZBA.
5. Samocha TM, Lawrence AL. Use of intensive nursery system in commercial shrimp production: advantages and disadvantages. In: Jory DE, editor. Proceedings of the First Latin American Shrimp Culture Congress and Exhibition. Grupo Ferias, Eventos y Congresos. Panama City, Panama; c1998 Oct 6-10.
6. Zelaya O, Davis A, Rouse DB. The influence of Artemia and algal supplements during the nursery phase of rearing pacific white shrimp, *Litopenaeus vannamei*. J World Aquacult Soc. 2007;38(4):486–96.
7. Persyn H, Aungst R. Global shrimp OP: 200I-Preliminary report-nursery. Global Aquacult Advocate. 2001;4(4):34-5.
8. Arnold SJ, Sellars MJ, Crocos PJ, Coman GJ. Intensive production of juvenile tiger shrimp Penaeus monodon: an evaluation of stocking density and artificial substrates. Aquaculture. 2006;261:890-6.
9. Gunalan B, Nina Tabitha S, Soundarapandian P, Anand T. An experimental study of the effects of different salinities on the growth and survival of L. vannamei. Cont. J Biol. Sci. 2013;6(2):1-8. DOI:10.5707/cjbiolsci.2013.6.2.1.8.
10. Gunalan B, Soundarapandian P, Kumaran R, Anand T, Kotiya AS. First report on White Spot Syndrome Virus (WSSV) infection in white leg shrimp *Litopenaeus vannamei* (Crustacea, Penaeidae) under semi intensive culture condition in India. AACL Bioflux. 2011;4(3):301-5.
11. Khanjani MH, Sajjadi MM, Alizadeh M, Sourinejad I. Nursery performance of Pacific white shrimp (*Litopenaeus vannamei* Boone, 1931) cultivated in a biofloc system: the effect of adding different carbon sources. Aquacult Res.; c2016. p. 1-11.
12. Wasielesky Jr W, Froes C, Foes G, Krummenauer D, Lara G, Poersch L. Nursery of *Litopenaeus vannamei* reared in a biofloc system: the effect of stocking densities and compensatory growth. J Shellfish Res. 2013;32:799-806.
13. Silva E, Silva J, Ferreira F, Soares M, Soares R, Peixoto S. Influence of stocking density on the zootechnical performance of *Litopenaeus vannamei* during the nursery phase in a biofloc system. Bol Inst Pesca. São Paulo. 2015;41(espe):777–83.
14. Peterson JJ, Griffith D. Intensive nursery systems. Global Aquacult Advocate. 1999;2:60-1.
15. Moss KK, Moss SM. Effects of artificial substrate and stocking density on the nursery production of pacific white shrimp *Litopenaeus vannamei*. J World Aquacult Soc. 2004;35(4):536-42.
16. Khanjani MH, Alizadeh M, Sharifinia M. Rearing of the Pacific white shrimp, *Litopenaeus vannamei* in a biofloc system: the effects of different food sources and salinity levels. Aquacult Nutr. 2020;26:328-37.
17. Godoy LC, Odebrecht C, Ballester E, Martins TG, Wasielesky Jr W. Effect of diatom supplementation during the nursery rearing of *Litopenaeus vannamei* (Boone, 1931) in a heterotrophic culture system. Aquacult Int. 2012;20:559-69.
18. Esparza-Leal HM, Pereira-Cardozo A, Wasielesky Jr. Performance of *Litopenaeus vannamei* postlarvae reared in indoor nursery tanks at high stocking density in clear-water versus biofloc system. Aquac Eng. 2015;68:28-34.
19. Tierney TW, Fleckenstein LJ, Ray AJ. The effects of density and artificial substrate on intensive shrimp *Litopenaeus vannamei* nursery production. Aquacult Eng. 2020;89:102063.
20. Peacor SD, Shiesari L, Werner EE. Mechanisms of nonlethal predator effect on cohort size variation: ecological and evolutionary implications. Ecology. 2007;8:1536–47.
21. Araneda ME, Hernández JM, Gasca-Leyva E, Vela MA. Growth modelling including size heterogeneity: application to the intensive culture of white shrimp (Penaeus vannamei) in freshwater. Aquaculture Engineering. 2013;56:1-12.
22. Filho MESdM, Owatari MS, Mourino JLP, Lapa KR, Soares HM. Application of nitrification and denitrification processes in a direct water reuse system for pacific white shrimp farmed in biofloc system. Aquaculture Engineering. 2020;88:102043.
23. Esparza-Leal HM, Xavier JAA, Wasielesky Jr W. Performance of *Litopenaeus vannamei* postlarvae reared in indoor nursery tanks under biofloc conditions at different salinities and zero-water exchange. Aquaculture International. 2016;24:1435–1447.
24. Luo Z, Liu L, Shan H, Tan. Using poly-beta-hydroxybutyric as an additional carbohydrate for biofloc in a shrimp *Litopenaeus vannamei* bioflocs nursery system with brackish water. Aquaculture. 2019;506:181-187.
25. Ponce-Palafox JT, Pavia AA, L´opez DGM, Arredondo-Figueroa JL, Lango-Reynoso F, Castañeda-Chávez, *et al*. Response surface analysis of temperature-salinity interaction effects on water quality, growth and survival of shrimp *Litopenaeus vannamei* postlarvae raised in biofloc intensive nursery production. Aquaculture. 2019;503:312-321.
26. Rezende Costa P, D. Dias Schleder, H. Ventura da Silva, F. Morais Henriques, M.A. de Lorenzo, W. Quadros Seiffert, E. Roberto Andreatta, F.d. Nascimento Vieira. Prenursery of the Pacific white shrimp in a biofloc system using different artificial substrates. Aquacultural Engineering. 2018;82:25-30. DOI: 10.1016/j.aquaeng.2018.04.001.
27. Krummenauer D, Samocha T, Poersch L, Lara G, Wasielesky Jr W. The reuse of water on the culture of Pacific white shrimp, *Litopenaeus vannamei*, in BFT system. Journal of World Aquaculture Society. 2014;45:3-14.

28. Fast AW, Boyd CE. Water circulation, aeration and other management practices. In: Fast AW, Lester LJ (Ed). Development in Aquaculture and Fisheries Science. NY: Elsevier; c1992. p. 457-495.
29. Cohen J, Samocha TM, Fox JM, Gandy RL, Lawrence AL. Characterization of water quality factors during intensive raceway production of juvenile *Litopenaeus vannamei* using limited discharge and biosecure management tools. Aquacultural Engineering. 2005;32:425-442.
30. Soundarapandian P, Gunalan B. Recent technology for the survival and production of giant tiger shrimp Penaeus monodon along South East Coast of India. International Journal of Zoological Research. 2008;4(1):21-27. DOI: http://dx.doi.org/10.3923/ijzr.2008.21.27
31. Ebeling JM, Timmons MB, Bisogni JJ. Engineering analysis of the stoichiometry of photoautotrophic, autotrophic, and heterotrophic removal of ammonia-nitrogen in aquaculture systems. Aquaculture. 2006;257:346-358.
32. Samocha TM, Patnaik S, Speed M, Ali AM, Burger JM, Almeida RV, *et al*. Use of molasses as carbon source in limited discharge nursery and grow-out systems for *Litopenaeus vannamei*. Aquacultural Engineering. 2007;36:184-191.
33. Avnimelech Y, Kochba M. Evaluation of nitrogen uptake and excretion by tilapia in biofloc tanks, using 15N tracing. Aquaculture. 2009;287:163-168. DOI: 10.1016/j.aquaculture.2008.10.009
34. Gao L, Shan HW, Zhang TW, Bao WZ, Ma SJ. Effects of carbohydrate addition on *Litopenaeus vannamei* intensive culture in a zero-water exchange system. Aquaculture. 2012;342:89-96.
35. Gaona CA, Poersch PL, Krummenauer HD, Foes GK, Wasielesky W. 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. 2011;2:54-73.
36. Anand T, Srinivasan A, Padmavathy P, Jawahar P, Sampathkumar J, Stephen. Nursery Rearing of Penaeus vannamei in Biofloc Systems with Different Salinities and Organic Carbon Sources. Indian Journal of Animal Research. 2022;56(4):392-399.