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# Hatchery performance of Pacific white shrimp, *Penaeus vannamei* in Biofloc technology by using different carbon sources

Kola Suneetha[1*], P. Padmavathi[1] and Darwin Chatla[1]

**Abstract**

The present study assessed the hatchery performance of *Penaeus vannamei* between the mysis 1 and postlarva 10 stages, in a zero-exchange biofloc system under three treatments with different carbon sources, fructose, lactose, and dextrose, in a 15:1 fixed C:N ratio with a stocking density of 100 $L^{-1}$ along with control treatment. The study used a stocking density of 100 $L^{-1}$. Water quality and survival performance were compared among treatments. The results revealed that adequate water quality parameters were more appropriate for production in the BFT treatment than in the control, and analysis of variance revealed that there were significant differences between treatment groups for $NO_2^-N$, $NO_3^-N$, and alkalinity ($P < 0.05$). Survival was significantly greater in the BFT treatment group than in the control group. Dextrose exhibited the highest survival rate for $PL_1$ at 93%, followed by fructose at 88.67% and lactose at 86.33%, while the control group had the lowest survival rate at 79.33% ($P > 0.05$). For $PL_5$ and $PL_{10}$, the survival rates were 90.67%, 85.67%, 78.33%, and 66.67% ($P < 0.05$) for dextrose, fructose, lactose, and the control, respectively. The study concluded that dextrose is the most effective carbon source for maintaining the hatchery system.

**Keywords** Biofloc, Carbon, Water quality, Survival

## Introduction

Fisheries and aquaculture are efficient protein production sectors that offer ample opportunities to alleviate poverty, hunger, and malnutrition [1]. Aquaculture has experienced phenomenal growth, with a global production of 178 million tonnes, and in India, the quantity increased from 0.79 MT in 1987 to 16.25 MT in 2022–23 [2]. Globally, India occupies the third position after China and Indonesia, with a share of 7.70% of the world's aquaculture production [1], and has achieved an impressive double-digit average annual growth rate of more than 10%, surpassing that of any other food production sector in the country over the past decade. It contributes approximately 1.24% to the country's gross value added (GVA) and more than 7.28% to the agricultural GVA (Indian Economic Survey, 2021–22). This sector has also witnessed significant export growth, with a total production of 12.22 MT valued at USD 1.42 billion in 2023 [3].

The vast resources in terms of water bodies and species of fish and shellfish in different agroecological regions of the country provide a wide array of culture systems and practices [4]. However, despite these resources, the rapid growth of the aquaculture industry is hampered because of several limitations, including the poor quality of seeds during the initial stages, raising concerns about the survival and growth of culturing species, which leads to limited productivity [5].

*Correspondence:
Kola Suneetha
suneetha.kola59@gmail.com
[1] Aquatic Biology Laboratory, Department of Zoology & Aquaculture, Acharya Nagarjuna University, Nagarjuna Nagar-522101, Andhra Pradesh, India

In the production line, the larval and postlarval stages are crucial components of the hatchery system for producing high-quality seeds. Generally, conventional shrimp hatchery systems are knotted with large amounts of water exchange to maintain adequate water quality parameters [6]. Minimizing water volume utilization in shrimp aquaculture systems may substantially reduce the expenses associated with water (i.e., pumping, collection, filtration, disinfection) and environmental impacts and enhance biosecurity for hatcheries [7]. Hence, the challenge in shrimp hatcheries is to determine a favorable water quality parameter with minimal/zero water exchange [8]. Furthermore, high stocking densities demand a greater food supply for reared species during the initial stages, raising concerns about survival and growth, which leads to limited productivity [9]. Hence, these concerns in the shrimp, larval, and postlarval stages need to be addressed in terms of technological advancements [10].

Biofloc technology (BFT) is an emerging technique that has gained momentum in recent years, with encouraging performance in aqua farming. Microbial manipulation allows cultured shrimp to grow more successfully [4, 11–16]. Microbial communities consist of microorganisms such as phytoplankton, bacteria, and organic matter, which serve as an extra food source for cultivable species. The fundamental premise of this technique is to recycle nutrients and nitrogenous wastes by manipulating the carbon:nitrogen (C:N) ratio in water to enhance the growth of heterotrophic bacteria [17]. These dense and active bacteria tend to produce biofloc, which shrimp can continually consume as a naturally occurring food supply. [18, 19].

Maintaining a balanced C:N ratio is essential for efficient waste bioconversion and a healthy BFT environment [20]. The selection of an appropriate carbon source can significantly impact floc formation, nutrient assimilation, and overall health and performance of the aquaculture species [21]. Carbon sources can be categorized as simple (easily degradable) or complex (slowly degradable). Simple sources like molasses, sugars, and starches are rapidly broken down by bacteria, while complex sources like brans (rice, wheat) and cellulose decompose at a slower rate. The choice of carbon source depends on various factors including cost, digestibility, and local availability. Commonly used options include molasses, glycerol, tapioca, and various brans [22]. Research is ongoing to identify new and sustainable sources to optimize BFT systems [23].

BFT aid in improving water quality under minimal/zero water exchange systems to maximize biosecurity [4]. In recent years, this technology has been adopted successfully in various aquatic species at different stages of production, including the broodstock [24–27], hatchery [28, 29], nursery [30–34], and grow-out phases [35–40]. However, there is limited information on the effectiveness of BFTs in the larval and postlarval stages of *P. vannamei*. Therefore, this study aimed to investigate the efficacy of BFTs in these stages by utilizing three different carbon sources.

## Materials and methods

### Experimental design

The present research was conducted with facilities acquired from the BKMN shrimp hatchery, which is situated in Undavalli (16°50′64" N and 80°57′13" E), Guntur district of Andhra Pradesh, India. The experimental setup included four treatments, consisting of three BFT treatments and a control treatment. The trials were conducted in eight 1000 L capacity HDPE circular tanks with a working volume of 800 L each. All the tanks were in the same capacity, and each group was randomly assigned to replicate. Prior to usage, the tanks were meticulously cleaned and treated with bleaching powder at 5 ppm. Subsequently, they were allowed to undergo dechlorination for 3 days. An aeration setup was installed at the bottom side of all the tanks to maintain proper dissolved oxygen (DO) levels in the water for shrimp and to sustain the suspension of solids produced during cultivation.

The SPF *Penaeus vannamei* shrimp nauplii were procured from the same hatchery after ensuring their disease-free status through specific PCR hatchery tests [41, 42]. The present experiment employed treated water with a salinity of 32 ppt. The larvae were reared at a carbon ratio of 15:1 [43] for three treatments using different carbon sources: BFT-I (fructose – $C_6H_{12}O_6$), BFT-II (lactose – $C_{12}H_{22}O_{11}$), and BFT-III (dextrose – $C_6H_{12}O_6$) and one control (without any addition of carbon source). Each experimental unit was stocked with 80,000 larvae in the mysis-1 stage ($M_1$), resulting in a stocking density of 100 larvae $L^{-1}$. The experiment continued for 13 days until the larvae reached postlarval stage 10 ($PL_{10}$). Throughout the experiment, water in the biofloc experimental units was not exchanged.

### Preparation of biofloc before stocking

For floc preparation, the treatment was started as per the protocol established by Avnimelech [43]. In brief, the process began on the first day with adding 1.5 g of ammonium chloride to introduce nitrogen into the system. Subsequently, carbon sources were added on the 3rd and 5th days at a rate of 5.62 g, followed by a doubling of the carbon sources to 11.25 g on the 7th day. The change in the color of the water from clear and transparent to light brown indicated the formation of flocs, which was attributed to the addition of carbon and nitrogen sources

from the external environment. On day 9, nauplii of *P. vannamei* (Mysis 1 stage) were introduced into all the prepared tanks at a density of 100 nos $L^{-1}$.

### Feed management

The larval and postlarval shrimp were fed INVE commercial microencapsulated diets (minimum protein content of 52%, minimum lipid content of 14.5%, maximum fiber content of 3%, and maximum moisture content of 10%) following the manufacturer's recommendations for each larval stage [28, 29]. The feeding schedule involved six daily feedings at specific times (06:00, 08:00, 10:00, 12:00, 14:00, 16:00, and 18:00), and the amount of feed, artemia, and carbon–nitrogen ratio were adjusted for each larval stage (Table 1). The feed quantity was calculated based on floc volume, while the feeding times remained the same throughout the study [43].

### Assessment of water quality parameters

The water quality of the experimental systems was checked daily. Water parameters such as temperature (mercury thermometer), pH (laboratory model Elico pH meter), salinity (hand refractometer), total ammonia nitrogen (TAN) using phenol hypochlorite method, dissolved oxygen (DO), ammonia ($NH_3$-N), nitrite ($NO_2$-N), nitrate ($NO_3$-N), and total alkalinity were analyzed following the American Public Health Association guidelines [44].

### Estimation of biofloc volume

Biofloc volume was quantified by employing an Imhoff cone daily to understand the dynamics of biofloc generation and to adopt control measures in the case of excess biofloc generation, if any as described by Avnimelech and Kochva [45]. These cones have marked graduations on their outer surface, which can be used to measure the volume of solids that settle from one liter of water in the rearing tank.

### Estimation of survival performance

Survival performance (%) was assessed at various larval and postlarval stages and was calculated as follows [46]:

$$SR\ (\%) = N_t/N_o\ X\ 100$$

where SR = survival (%), $N_t$ = the number of shrimps that survived until the end of the experiment, and $N_o$ = the number of shrimps that were available at the beginning of the experiment.

### Statistical analysis

All the values are presented as the mean ± standard deviation (SD) of three replicate analyses. One-way analysis of variance (ANOVA) followed by Duncan's multiple range test (DMRT) was carried out by IBM SPSS software (version 29) at the 0.05 level ($P < 0.05$) of significance.

**Table 1** Feeding regimes for *P. vannamei* between the $M_1$ and $PL_{10}$ phases

| Treatment | Daily Input | Mysis | | | Post larvae | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $M_1$ | $M_2$ | $M_3$ | $PL_1$ | $PL_2$ | $PL_3$ | $PL_4$ | $PL_5$ | $PL_6$ | $PL_7$ | $PL_8$ | $PL_9$ | $PL_{10}$ |
| **BFT-I** | Diet (g $tank^{-1}$) | 0.8 | 0.8 | 0.8 | 0.8 | 0.96 | 1.12 | 1.28 | 1.44 | 1.6 | 1.2 | 1.6 | 2 | 2.2 |
| | Artemia (g $tank^{-1}$) | 0.696 | 1.046 | 1.046 | 1.046 | 1.046 | 1.046 | 1.046 | 1.046 | 1.046 | 1.046 | 1.046 | 1.046 | 1.046 |
| | N (g $tank^{-1}$) | 0.04 | 0.04 | 0.04 | 0.04 | 0.05 | 0.067 | 0.075 | 0.086 | 0.097 | 0.072 | 0.097 | 0.12 | 0.14 |
| | Fructose (g $tank^{-1}$) | 0.6 | 0.6 | 0.6 | 0.6 | 0.75 | 1.005 | 1.125 | 1.29 | 1.455 | 1.08 | 1.455 | 1.8 | 2.1 |
| | C: N | 15:01 | 15:01 | 15:01 | 15:01 | 15:01 | 15:01 | 15:01 | 15:01 | 15:01 | 15:01 | 15:01 | 15:01 | 15:01 |
| **BFT-II** | Diet (g $tank^{-1}$) | 0.8 | 0.8 | 0.8 | 0.8 | 0.96 | 1.12 | 1.28 | 1.44 | 1.6 | 1.2 | 1.6 | 2 | 2.2 |
| | Artemia (g $tank^{-1}$) | 0.696 | 1.046 | 1.046 | 1.046 | 1.046 | 1.046 | 1.046 | 1.046 | 1.046 | 1.046 | 1.046 | 1.046 | 1.046 |
| | N (g $tank^{-1}$) | 0.04 | 0.04 | 0.04 | 0.04 | 0.05 | 0.067 | 0.075 | 0.086 | 0.097 | 0.072 | 0.097 | 0.12 | 0.14 |
| | Lactose (g $tank^{-1}$) | 0.6 | 0.6 | 0.6 | 0.6 | 0.75 | 1.005 | 1.125 | 1.29 | 1.455 | 1.08 | 1.455 | 1.8 | 2.1 |
| | C: N | 15:01 | 15:01 | 15:01 | 15:01 | 15:01 | 15:01 | 15:01 | 15:01 | 15:01 | 15:01 | 15:01 | 15:01 | 15:01 |
| **BFT-III** | Diet (g $tank^{-1}$) | 0.8 | 0.8 | 0.8 | 0.8 | 0.96 | 1.12 | 1.28 | 1.44 | 1.6 | 1.2 | 1.6 | 2 | 2.2 |
| | Artemia (g $tank^{-1}$) | 0.696 | 1.046 | 1.046 | 1.046 | 1.046 | 1.046 | 1.046 | 1.046 | 1.046 | 1.046 | 1.046 | 1.046 | 1.046 |
| | N (g $tank^{-1}$) | 0.04 | 0.04 | 0.04 | 0.04 | 0.05 | 0.067 | 0.075 | 0.086 | 0.097 | 0.072 | 0.097 | 0.12 | 0.14 |
| | Dextrose (g $tank^{-1}$) | 0.6 | 0.6 | 0.6 | 0.6 | 0.75 | 1.005 | 1.125 | 1.29 | 1.455 | 1.08 | 1.455 | 1.8 | 2.1 |
| | C: N | 15:01 | 15:01 | 15:01 | 15:01 | 15:01 | 15:01 | 15:01 | 15:01 | 15:01 | 15:01 | 15:01 | 15:01 | 15:01 |
| **Control** | Diet (g $tank^{-1}$) | 0.8 | 0.8 | 0.8 | 0.8 | 0.96 | 1.12 | 1.28 | 1.44 | 1.6 | 1.2 | 1.6 | 2 | 2.2 |
| | Artemia (g $tank^{-1}$) | 0.696 | 1.046 | 1.046 | 1.046 | 1.046 | 1.046 | 1.046 | 1.046 | 1.046 | 1.046 | 1.046 | 1.046 | 1.046 |

*C* Carbon, *N* Nitrogen

## Results and discussion

### Water quality parameters

Table 2 summarizes the water quality parameters observed in the study. The water quality parameters in the BFT treatments were similar, and analysis of variance revealed that there were significant differences between treatment groups for $NO_2^-N$, $NO_3^-N$, and alkalinity ($P < 0.05$). The DO levels of lactose and dextrose treatments showed no significant differences except for the fructose which had significantly lower DO values than that of lactose and dextrose ($P < 0.05$). All the observed parameters remained similar to those found in conventional hatchery systems with high levels of water exchange. The BFT hatchery systems showed similar results with the addition of carbon sources to *P. vannamei*, as reported by de Lorenzo et al. [28].

In shrimp hatchery systems, it is crucial to manage water quality parameters carefully to ensure the optimal survival and viability of the shrimp. Any variations in these parameters beyond a certain range can have a severe impact on production and result in significant economic losses [47]. Temperature is one of the most important factors influencing physiological responses in organisms, such as respiration, metabolism, growth, and reproduction [48]. Cultured shrimp grow best at temperatures ranging from 24 to 32 °C [49]. During the study, the average temperature ranged from 27 °C to 29 °C, which was the optimal temperature for all the treatments. Well-maintained aeration for a sufficient supply of DO is necessary for shrimp and for the formation of biofloc [50]. The lethal DO concentration for *P. vannamei* has been reported to be 1.0 ppm [51]. The DO levels ranged from 5.30 to 6.24 mg $L^{-1}$ in all the tanks. The lower pH values were possibly a result of high respiration rates by a large number of microorganisms, which may have increased carbon dioxide concentrations. The permissible pH limit for *P. vannamei* is 7.5 to 8.5 [52]. The pH was significantly lower in the BFT, ranging from 7.54 to 7.83, than in the control (8.05). Similarly, the TAN levels were significantly lower (0.69 to 0.78 mg $L^{-1}$) than those in the control (1.07 mg $L^{-1}$). These lower levels may be caused by the inclusion of carbon sources. However, the mean values of pH and TAN in the BFT treatments remained at optimum levels throughout the experiment [46].

Ammonia ($NH_3^-N$) and nitrite ($NO_2^-N$) are highly toxic to cultured shrimp. High nitrite concentrations have been shown to significantly impact the circulatory and immune systems of aquatic organisms [53]. The concentration of $NH_3^-N$ ranged from 0.12 to 0.36 mg $L^{-1}$. The $NH_3^-N$ was significantly lower in the BFT (0.12 mg $L^{-1}$) than in the control (0.36 mg $L^{-1}$). The levels of $NO_2^-N$ ranged from 0.06 to 1.53 mg $L^{-1}$. The lowest concentrations were observed in the BFT (0.06 mg $L^{-1}$), while the highest were found in the control treatment (1.53 mg $L^{-1}$), which is unfavorable for optimal culture conditions [54]. For a successful *P. vannamei* culture, the optimal $NO_2^-N$ concentration is < 1.0 mg $L^{-1}$ [55]. Nitrate ($NO_3^-N$) is an inorganic nitrogen compound formed at the end of the nitrification process. The concentration of nitrate is usually greater than that of ammonia and nitrite [56]. High levels of nitrate have been shown to affect the osmoregulation and oxygen transport of cultured aquatic species [57]. In the BFT treatments, the observed nitrate values ranged from 1.94 to 2.05 mg $L^{-1}$, lower than those in the control groups, which had a value of 2.77 mg $L^{-1}$. These results for nitrate are similar to those reported by Furtado et al. [58]. The relatively stable concentrations of $NH_3^-N$, $NO_2^-N$, and $NO_3$-N in the BFT treatments may be attributed to effective nitrification processes. Alkalinity, which is the buffering capacity of water, can

**Table 2** Water quality parameters of *P. vannamei* between the $M_1$ and $PL_{10}$ phases

| Parameter | Biofloc treatments | | | Control |
|---|---|---|---|---|
| | Fructose | Lactose | Dextrose | |
| Temperature (°C) | 28.34 ± 0.46 | 29.16 ± 0.33 | 28.80 ± 0.33 | 29.63 ± 0.13 |
| DO (mg $L^{-1}$) | 5.81 ± 0.09$^{ab}$ | 5.96 ± 0.09$^{c}$ | 6.24 ± 0.32$^{c}$ | 5.30 ± 0.10$^{a}$ |
| Salinity (g $L^{-1}$) | 32.05 ± 0.03 | 32.27 ± 0.18 | 32.11 ± 0.06 | 32.29 ± 0.10 |
| pH | 7.54 ± 0.20 | 7.83 ± 0.14 | 7.70 ± 0.15 | 8.05 ± 0.29 |
| TAN (mg $L^{-1}$) | 0.78 ± 0.04 | 0.69 ± 0.02 | 0.72 ± 0.02 | 1.07 ± 0.34 |
| $NH_3^-N$ (mg $L^{-1}$) | 0.18 ± 0.13 | 0.12 ± 0.02 | 0.23 ± 0.17 | 0.36 ± 0.03 |
| $NO_2^-N$ (mg $L^{-1}$) | 0.13 ± 0.06$^{a}$ | 0.16 ± 0.10$^{a}$ | 0.06 ± 0.04$^{b}$ | 1.53 ± 0.17$^{a}$ |
| $NO_3^-N$ (mg $L^{-1}$) | 1.94 ± 0.11$^{b}$ | 2.05 ± 0.04$^{b}$ | 2.00 ± 0.07$^{b}$ | 2.77 ± 0.14$^{a}$ |
| Alkalinity (mg $L^{-1}$) | 127.92 ± 1.00$^{b}$ | 128.17 ± 0.27$^{b}$ | 127.08 ± 0.58$^{b}$ | 91.38 ± 0.57$^{a}$ |

All the values are the means ± SD (standard deviation) of three replicate analyses

Data with different superscript letters in the same row are significantly different ($P < 0.05$)

*DO* Dissolved oxygen, *TAN* Total ammonia nitrogen, *$NH_3^-N$* Ammonia, *$NO_2^-N$* Nitrite, *$NO_3^-N$* Nitrate

significantly impact primary productivity [59]. In the present investigation, the alkalinity of the BFT ranged from 127.08–128.17 mg $L^{-1}$, which was significantly greater than that of the control (91.38 mg $L^{-1}$).

### Biofloc volume

The volume of biofloc increased gradually in all treatments over time (Fig. 1); however, the greatest floc volume was observed for dextrose (1.62 ml $L^{-1}$), followed by fructose (1.12 ml $L^{-1}$) and lactose (0.84 ml $L^{-1}$). Similar levels of floc volume were reported by Panigrahi et al. [46]. However, the lowest floc volume could be because lactose, being a disaccharide, is harder to break down than monosaccharides such as dextrose and fructose, resulting in less floc. Compared to fructose, dextrose is derived from simple starch, which makes it easier to break down and thus forms flocs more easily.

### *Survival performance*

The percentages of the survival rates for different treatments are presented in Table 3. The highest survival rate for $PL_1$ was observed for dextrose (93%), followed by fructose (88.67%) and lactose (86.33%), while the lowest survival rate was in the control group (79.33%) ($P > 0.05$). For $PL_5$ and $PL_{10}$, the trends were similar; the survival rates were 90.67%, 85.67%, 78.33%, and 66.67% for the dextrose, fructose, lactose, and control treatments, respectively. One-way ANOVA showed that there were no significant differences ($P > 0.05$) in the mean percentages of $PL_5$ and $PL_{10}$ among the different treatments. However, when comparing $PL_5$ fructose and dextrose treatments, there were no significant differences except for lactose, which had significantly lower survival values.

In biofloc technology, maintaining a suitable carbon–nitrogen ratio is crucial. The choice of carbohydrate source is one of the main factors since different carbon sources have different effects on cultured species [33, 60, 61]. In this study, $M_1$ to $PL_{10}$ were reared under three treatments with different carbon sources—fructose, lactose, and dextrose—at a ratio of 15:1, and the control treatment without the addition of a carbohydrate source. The average survival rate was significantly greater in the BFT treatment group (71% to 86%) than in the control group (53%). Similar studies have shown that the survival of shrimp in BFTs ranges from 80 to 100% of that of control shrimp [40, 62, 63]. The current results showed higher survival levels than those of de Lorenzo et al. [28, 29] under the carbon source dextrose, which may be due to the lower stocking density of larvae adapted to the present study. The overall survival in all biofloc-treated groups surpassed the rate appropriate for the species (70%, [64]) and that appropriate for the experimental hatcheries [28, 29, 65, 66]. Based on these results, among all the carbon sources used, fertilization with dextrose can be efficiently maintained in the hatchery system.

**Table 3** Survival performance of *P. vannamei* between the $M_1$ and $PL_{10}$ stages

| Larval stage | Treatments (%) | | | |
|---|---|---|---|---|
| | Fructose | Lactose | Dextrose | Control |
| $M_1$ Stocked | 100 nos $L^{-1}$ | 100 nos $L^{-1}$ | 100 nos $L^{-1}$ | 100 nos $L^{-1}$ |
| $PL_1$ | 88.67 ± 2.33 | 86.33 ± 5.81 | 93.00 ± 3.61 | 79.33 ± 2.33 |
| $PL_5$ | 85.67 ± 2.96$^{b}$ | 78.33 ± 4.33$^{ab}$ | 90.67 ± 4.37$^{b}$ | 66.67 ± 4.41$^{a}$ |
| $PL_{10}$ | 80.33 ± 4.70$^{bc}$ | 71.33 ± 2.40$^{b}$ | 86.33 ± 3.84$^{c}$ | 53.71 ± 3.39$^{a}$ |

All the values are the means ± SD (standard deviation) of three replicate analyses

Data with different superscript letters in the same row are significantly different ($P < 0.05$)

*M* Mysis, *PL* Post Larva

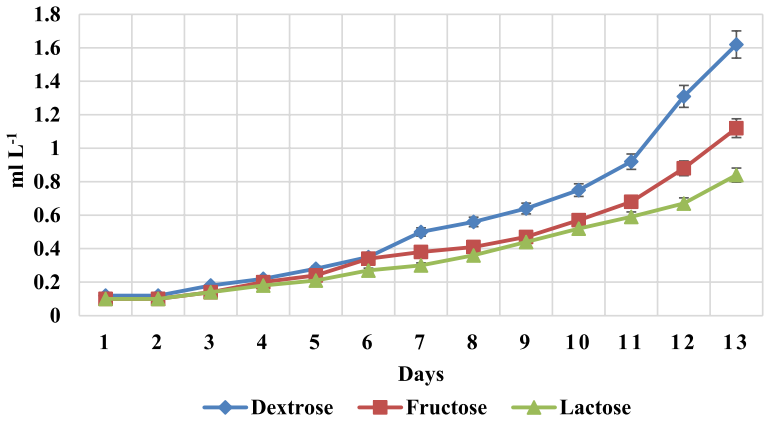


**Fig. 1** Floc volume in biofloc treatments

## Conclusion

BFT systems have been driven toward increased sustainability in shrimp aquaculture. The types of carbon sources and addition strategies are critical considerations in BFT systems. The current study contributes to a better understanding of the effects of different carbon sources on the *P. vannamei* hatchery system. Based on the present findings, it can be concluded that using dextrose, fructose, and lactose as carbon sources at a ratio of 15:1 without water exchange resulted in adequate water quality. Additionally, *P. vannamei* showed a greater survival rate during the $M_1$ and $PL_{10}$ hatchery phases when dextrose was used than during the other treatments.

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**Authors' contributions**
S.K.; Conceptualization, methodology, investigation, formal analysis, writing - original draft. P.P.; supervision, writing - review & editing. D. C.; Data – curation & preparation. S.K., P.P., and D.C. have read and agreed to the published version of the manuscript.

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**Availability of data and materials**
This article contains all of the data that were analyzed for this study and can be obtained from the corresponding author if needed.

**Data availability**
No datasets were generated or analysed during the current study.

## Declarations

**Ethics approval and consent to participate**
Not applicable.

**Consent for publication**
Not applicable.

**Competing interests**
The authors declare no competing interests.

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**References**

1. FAO. The State of World Fisheries and Aquaculture 2022. Toward Blue Transformation. Rome: FAO; 2022. p. 266.
2. DoF. Department of Fisheries 2022. New Delhi: Ministry of Fisheries, Animal Husbandry and Dairying; 2022. p. 150.
3. PIB. Press Information Bureau Government of India. Year End Review 2023: Department of Fisheries (Ministry of Fisheries, Animal Husbandry and Dairying), 2023:1986155.
4. Chatla D, Padmavathi P, Srinu G. Wastewater treatment techniques for sustainable aquaculture. In: Waste management as economic industry toward circular economy. 2020. p. 159–66.
5. Boyd CE, D'Abramo LR, Glencross BD, Huyben DC, Juarez LM, Lockwood GS, McNevin AA, Tacon AG, Teletchea F, Tomasso JR Jr, Tucker CS, Valenti WC. Achieving sustainable aquaculture: Historical and current perspectives and future needs and challenges. J World Aquaculture Soc. 2020;51(3):578–633.
6. New MB & Kutty MN. Commercial freshwater prawn farming and enhancement around the world. In: New MB, Valenti WC, Tidwell JH, D'Abramo LR, & Kutty MN, editors. Freshwater prawns: biology and farming. Oxford Wiley-Blackwell; 2010. p. 346–99.
7. Menasveta P. Improved shrimp growout systems for disease prevention and environmental sustainability in Asia. Rev Fish Sci. 2002;10(3–4):391–402.
8. Ray AJ, Seaborn G, Leffler JW, Wilde SB, Lawson A, Browdy CL. Characterization of microbial communities in minimal-exchange, intensive aquaculture systems and the effects of suspended solids management. Aquaculture. 2010;310(1–2):130–8.
9. Mugwanya M, Dawood MA, Kimera F, Sewilam H. Biofloc systems for sustainable production of economically important aquatic species: A review. Sustainability. 2021;13(13):7255.
10. Emerenciano MG, Rombenso AN, Vieira FDN, Martins MA, Coman GJ, Truong HH, Noble TH, Simon CJ. Intensification of penaeid shrimp culture: an applied review of advances in production systems, nutrition, and breeding. Animals. 2022;12(3):236.
11. El-Sayed AFM. Use of biofloc technology in shrimp aquaculture: a comprehensive review, with emphasis on the last decade. Rev Aquac. 2021;13(1):676–705.
12. Khanjani MH, Sharifinia M. Biofloc technology with addition molasses as carbon sources applied to *Litopenaeus vannamei* juvenile production under the effects of different C/N ratios. Aquacult Int. 2022;30(1):383–97.
13. Khanjani MH, Mozanzadeh MT, Sharifinia M & Emerenciano MGC. Broodstock and seed production in biofloc technology (BFT): an updated review focused on fish and penaeid shrimp. Aquaculture. 2023;579(30):740278.
14. Pinto PHO, Rocha JL, do Vale Figueiredo JP, Carneiro RFS, Damian C, de Oliveira L, Seiffert WQ. Culture of marine shrimp (*Litopenaeus vannamei*) in biofloc technology system using artificially salinized freshwater: Zootechnical performance, economics and nutritional quality. Aquaculture. 2020;520:734960.
15. Suneetha K, Padmavathi P. Sustainable Aquaculture through Recycling of Waste Nutrients using Biofloc Technology. Int J Basic Appl Res. 2019;9(5):588–99.
16. Yu YB, Choi JH, Lee JH, Jo AH, Lee JW, Choi HJ., ... & Kim JH. The use, application and efficacy of biofloc technology (BFT) in shrimp aquaculture industry: A review. Environ TechnolInnov. 2024;33:103345.
17. Sun Y, Zhang J, Dong D, Li M, Yang X, Song X, Li X. Effects of carbon source addition strategies on water quality, growth performance, and microbial community in shrimp BFT aquaculture systems. Aquaculture. 2024;578:740027.
18. Burford MA, Thompson PJ, McIntosh RP, Bauman RH, Pearson DC. The contribution of flocculated material to shrimp (*Litopenaeus vannamei*) nutrition in a high-intensity, zero-exchange system. Aquaculture. 2004;232(1–4):525–37.
19. Wasielesky W Jr, Atwood H, Stokes A, Browdy CL. Effect of natural production in a zero exchange suspended microbial floc based super-intensive culture system for white shrimp *Litopenaeus vannamei*. Aquaculture. 2006;258(1–4):396–403.
20. Suneetha K, Kavitha K, Darwin CH. Biofloc Technology: an emerging tool for sustainable aquaculture. Int J Zool Stud. 2018;3:87–90.
21. Abakari G, Luo G, Kombat EO, Alhassan EH. Supplemental carbon sources applied in biofloc technology aquaculture systems: Types, effects and future research. Rev Aquac. 2021;13(3):1193–222.
22. Martínez-Córdova LR, Emerenciano M, Miranda-Baeza A, Martínez-Porchas M. Microbial-based systems for aquaculture of fish and shrimp: an updated review. Rev Aquac. 2015;7(2):131–48.
23. McCusker S, Warberg MB, Davies SJ, Valente CDS, Johnson MP, Cooney R, Wan AH. Biofloc technology as part of a sustainable aquaculture system: a review on the status and innovations for its expansion. Aquac Fish Fisheries. 2023;3(4):331–52.

24. Ekasari J, Zairin M, Putri DU, Sari NP, Surawidjaja EH, Bossier P. Biofloc-based reproductive performance of Nile tilapia *Oreochromis niloticus* L. broodstock. Aquac Res. 2015;46(2):509–12.
25. Magaña-Gallegos E, Arévalo M, Cuzon G, Gaxiola G. Effects of using the biofloc system and eyestalk ablation on reproductive performance and egg quality of *Litopenaeus vannamei* (Boone, 1931) (Decapoda: Dendrobranchiata: Penaeidae). Anim Reprod Sci. 2021;228:106749.
26. Magaña-Gallegos E, González-Zúñiga R, Cuzon G, Arevalo M, Pacheco E, Valenzuela MA, Gaxiola G, Chan-Vivas E, López-Aguiar K, Noreña-Barroso E. Nutritional contribution of biofloc within the diet of growout and broodstock of *Litopenaeus vannamei*, determined by stable isotopes and fatty acids. J World Aquaculture Soc. 2018;49(5):919–32.
27. Zafar MA, Rana MM. Biofloc technology: an eco-friendly "green approach" to boost up aquaculture production. Aquacult Int. 2022;30(1):51–72.
28. de Lorenzo MA, Candia EWS, Schleder DD, Rezende PC, Seiffert WQ, do Nascimento Vieira, F. Intensive hatchery performance of Pacific white shrimp in the biofloc system under three different fertilization levels. Aquacult Eng. 2016;72:40–4.
29. de Lorenzo MA, Poli MA, Candia EWS, Schleder DD, Rodrigues MS., Guimarães AM., ... & do Nascimento Vieira, F. Hatchery performance of the pacific white shrimp in biofloc system using different stocking densities. Aquac Eng. 2016;75:46–50.
30. Correia ES, Wilkenfeld JS, Morris TC, Wei L, Prangnell DI, Samocha TM. Intensive nursery production of the Pacific white shrimp *Litopenaeus vannamei* using two commercial feeds with high and low protein content in a biofloc-dominated system. Aquacult Eng. 2014;59:48–54.
31. 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. Aquac Res. 2017;48(4):1491–501.
32. Tierney TW, Ray AJ. Comparing biofloc, clear-water, and hybrid nursery systems (Part I): Shrimp (*Litopenaeus vannamei*) production, water quality, and stable isotope dynamics. Aquacult Eng. 2018;82:73–9.
33. Tinh TH, Koppenol T, Hai TN, Verreth JA, Verdegem MC. Effects of carbohydrate sources on a biofloc nursery system for whiteleg shrimp (*Litopenaeus vannamei*). Aquaculture. 2021;531:735795.
34. Wasielesky W Jr, Bezerra A, Poersch L, Hoffling FB, Krummenauer D. Effect of feeding frequency on the white shrimp *Litopenaeus vannamei* during the pilot-scale nursery phase of a superintensive culture in a biofloc system. J World Aquaculture Soc. 2020;51(5):1175–91.
35. Cavalcanti NR, Costa CB, Rodrigues F, Soares R, Bezerra RDS, Peixoto S. Effect of feeding frequency on growth and digestive enzyme activity in *Litopenaeus vannamei* during the grow-out phase in biofloc system. Aquac Nutr. 2019;25(3):577–84.
36. Huang HH, Liao HM, Lei YJ, Yang PH. Effects of different carbon sources on growth performance of *Litopenaeus vannamei* and water quality in the biofloc system in low salinity. Aquaculture. 2022;546:737239.
37. Khanjani MH, Sharifinia M. Biofloc technology as a promising tool to improve aquaculture production. Rev Aquac. 2020;12(3):1836–50.
38. Marimuthu S, Puvaneswari S & Lakshmanan R. Effect of biofloc technology enriches the growth of *Litopenaeus vannamei* (Boone, 1931). Appl Biochem Biotechnol. 2024;96(7):3860–90.
39. Serra FP, Gaona CA, Furtado PS, Poersch LH, Wasielesky W. Use of different carbon sources for the biofloc system adopted during the nursery and grow-out culture of *Litopenaeus vannamei*. Aquacult Int. 2015;23:1325–39.
40. Xu WJ, Morris TC, Samocha TM. Effects of C/N ratio on biofloc development, water quality, and performance of *Litopenaeus vannamei* juveniles in a biofloc-based, high-density, zero-exchange, outdoor tank system. Aquaculture. 2016;453:169–75.
41. Balasubramanian CP, Anand S, Kannappan S, Biju IF. Training manual on recent advances in farming of pacific white shrimp (*Penaeus vannamei*). ICAR-CIBA, Training Manual Series, Chennai. 2018;14:126.
42. Lal KK, Jithendran KP, Sairam CV, Muralidhar M, Jayanthi M, Balasubramanian CP, Angel JRJ. Training Manual on shrimp culture and Disease management in Inland Saline Areas. ICAR-CIBA, Training Manual Series, Chennai. 2022;30:177.
43. Avnimelech Y. Carbon/nitrogen ratio as a control element in aquaculture systems. Aquaculture. 1999;176(3–4):227–35.
44. APHA. Standard Methods of Water and Wastewater. 21st Edn., American Public Health Association, Washington, DC., ISBN: 0875530478, 2005. pp: 2–61.
45. Avnimelech Y, Kochba M. Evaluation of nitrogen uptake and excretion by tilapia in bio floc tanks, using15N tracing. Aquaculture. 2009;287(1–2):163–8.
46. Panigrahi A, Sundaram M, Chakrapani S, Rajasekar S, Syama Dayal J, Chavali G. Effect of carbon and nitrogen ratio (C: N) manipulation on the production performance and immunity of Pacific white shrimp *Litopenaeus vannamei* (Boone, 1931) in a biofloc-based rearing system. Aquac Res. 2019;50(1):29–41.
47. Mohanty RK, Ambast SK, Panigrahi P, Mandal KG. Water quality suitability and water use indices: Useful management tools in coastal aquaculture of *Litopenaeus vannamei*. Aquaculture. 2018;485:210–9.
48. Zweig RD, Morton JD, Stewart MM. Source water quality for aquaculture: a guide for assessment. World Bank. 1999;23764:1–76.
49. González RA, Díaz F, Licea A, Re AD, Sánchez LN, García-Esquivel Z. Thermal preference, tolerance and oxygen consumption of adult white shrimp *Litopenaeus vannamei* (Boone) exposed to different acclimation temperatures. J Therm Biol. 2010;35(5):218–24.
50. Verdegem M, Buschmann AH, Latt UW, Dalsgaard AJ, Lovatelli A. The contribution of aquaculture systems to global aquaculture production. J World Aquaculture Soc. 2023;54(2):206–50.
51. Hopkins JS, Stokes AD, Browdy CL, Sandifer PA. The relationship between feeding rate, paddlewheel aeration rate and expected dawn dissolved oxygen in intensive shrimp ponds. Aquacult Eng. 1991;10(4):281–90.
52. Wang X, Ma S, Dong S, Cao M. Effects of salinity and dietary carbohydrate levels on growth and energy budget of juvenile *Litopenaeus vannamei*. J Shellfish Res. 2004;23(1):231–7.
53. Schuler DJ. Acute toxicity of ammonia and nitrite to white shrimp *L. vannamei* at low salinities.Doctoral dissertation, Master thesis, Virginia Polytechnic Institute and State University; 2008.
54. Kavitha K, Suneetha K, Darwin CH, Selvakumar P, Muddula Krishna N, Govinda Rao V. Evaluation of water quality in biofloc and non biofloc systems of pacific white shrimp, *Litopenaeus vannamei* (Boone, 1931). Int J Adv Educ Res. 2017;2(6):14–7.
55. Kirchman DL. The uptake of inorganic nutrients by heterotrophic bacteria. Microb Ecol. 1994;28:255–71.
56. Robles-Porchas GR, Gollas-Galván T, Martínez-Porchas M, Martínez-Cordova LR, Miranda-Baeza A, Vargas-Albores F. The nitrification process for nitrogen removal in biofloc system aquaculture. Rev Aquac. 2020;12(4):2228–49.
57. Valencia-Castañeda G, Frías-Espericueta MG, Vanegas-Pérez RC, Chávez-Sánchez MC, Páez-Osuna F. Physiological changes in the hemolymph of juvenile shrimp *Litopenaeus vannamei* to sublethal nitrite and nitrate stress in low-salinity waters. Environ Toxicol Pharmacol. 2020;80:103472.
58. Furtado PS, Campos BR, Serra FP, Klosterhoff M, Romano LA, Wasielesky W. Effects of nitrate toxicity in the Pacific white shrimp, *Litopenaeus vannamei*, reared with biofloc technology (BFT). Aquacult Int. 2015;23:315–27.
59. Boyd CE, Tucker CS, Somridhivej B. Alkalinity and hardness: critical but elusive concepts in aquaculture. J World Aquaculture Soc. 2016;47(1):6–41.
60. Crab R. Bioflocs technology: an integrated system for the removal of nutrients and simultaneous production of feed in aquaculture (Doctoral dissertation, Ghent University). 2010.
61. Wei Y, Liao SA, Wang AL. The effect of different carbon sources on the nutritional composition, microbial community and structure of bioflocs. Aquaculture. 2016;465:88–93.
62. Anand PS, Kumar S, Panigrahi A, Ghoshal TK, Syama Dayal J, Biswas G, Sundaray JK, De D, Ananda Raja R, Deo AD, Ravichandran P. Effects of C: N ratio and substrate integration on periphyton biomass, microbial dynamics and growth of *Penaeus monodon* juveniles. Aquacult Int. 2013;21:511–24.
63. Panjaitan P. Effect of C: N ratio levels on water quality and shrimp production parameters in *Penaeus monodon* shrimp culture with limited water exchange using molasses as a carbon source. ILMU KELAUTAN: Indonesian J Mar Sci. 2011;16(1):1–8.
64. FAO. Health management and biosecurity maintenance in white shrimp (*Penaeus vannamei*) hatcheries in Latin America. Rome: FAO; 2003. p. 62.
65. Aranguren LF, Briñez B, Aragón L, Platz C, Caraballo X, Suarez A, Salazar M. Necrotizing hepatopancreatitis (NHP) infected *Penaeus vannamei* female broodstock: Effect on reproductive parameters, nauplii and larvae quality. Aquaculture. 2006;258(1–4):337–43.
66. Louis RD, Perez EI, Sangha R, Puello-Cruz A. Successful culture of larvae of *Litopenaeus vannamei* fed a microbound formulated diet exclusively from either stage PZ2 or M1 to PL1. Aquaculture. 2006;261(4):1356–62.


## Publisher's Note