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Effect of Biofloc on growth performance and survival of *Litopenaeus vannamei* (Boone, 1931) nursery phase at different salinities

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Abstract
Biofloc technology is considered as sustainable, environment-friendly and cost-effective technology for shrimp aquaculture due to its several beneficial effects such as disease prevention, water quality maintenance, and growth performance. Present research work was designed to compare the growth performance and survival of *Litopenaeus vannamei* nursery phase under biofloc at different saline condition. A 45 days experiment trial was carried out at different salinities (10, 20, 30, 35, 40, 50 and 60 ppt) with and without biofloc. The growth parameters were analysis end of the experiment after forty-five days. Specific growth was measured fourth night. The growth performance of *L. vannamei* was found better in 20, 30 and 35 compared to control. Average body weight gain, protein efficiency ratio, and feed efficiency ratio, specific growth ratio, FCR and survival percentage was found better in treatment. Hence it can be concluded that 20, 30 and 35 ppt under biofloc is most suitable for culture as compared to other salinities.

Keywords: *L. vannamei*, Biofloc, growth & survival, different salinity

1. Introduction
Aquaculture is one the fastest growing food producing sector in the world. It provides nutrition, food security, income and livelihoods for over hundreds of millions of people, contributing around 46% of world total food fish production. The global fisheries production was 179 million tonnes in 2018. Of which, aquaculture production was reported 82.1 million tonnes (Anon., 2020a) [1]. World per capita fish supply reached a new record high of 20.5 kg in 2018. World population is growing rapidly and by 2050 it is expected to cross 9 billion and for that food production needs to be doubled to fulfil the demand. Supply of nutritionally balanced and high quality protein food to growing population is a major challenge the world over. Indian aquaculture is undergoing rapid developments towards achieving the goal of blue revolution and holding the second rank in the world aquaculture. India has showcased phenomenal growth in fisheries production rising from 0.75 MT in 1950-51 to around 12.89 million tonnes of seafood worth Rs 46,662.85 crore (USD 6.68 billion) during 2019-20 (Anon., 2020b) [2].

Shrimp farming is the key player which has changed the face of aquaculture around the globe. Indian shrimp aquaculture industry has undergone remarkable transformations during the last 10 years. The export of the white leg shrimp *Litopenaeus vannamei*, has improved from 4,18,128 MT to 5,12,189 MT in 2019-20 (Anon., 2020b) [2]. Due to fast growing shrimp aquaculture industry, there is requirement for development of post larvae (PLs) nursery rearing system. This can improve shrimp seed quality, survival, high resistance against diseases, less environmental stress and reduced culture period.

Among the many prevailing technologies, the biofloc technology is promising for development of sustainable aquaculture. Biofloc technology is a modern technology emphasized majorly on improving environmental control over aquatic animal production and it can solve some of the major problem facing the conventional shrimp farming system. Biofloc can be considered as sustainable, environment-friendly and cost-effective technology which can be used to develop a zero water exchange culture system to avoid the problem of waste generation and discharge. In this technique, the aerobic decomposition of the organic matter were allow by using constant aeration and addition of carbohydrates for maintained high levels of microbial floc. These actuate the growth of heterotrophic bacteria and enhance uptake of

nitrogen from water. Those bacteria produce microbial proteins which are used by the shrimp as food sources. Thus, nutrients can recycle and reused sustainably to improve shrimp production with the minimal exchange of water.

The application of biofloc technology is still at a very early stage in aquaculture operations in India. Biofloc can be enounced as a complex community of organic material associate with other bloc, which creat mass suspended particles (Cuzon *et al.*, 2004; Emerenciano *et al.*, 2012; Emerenciano *et al.*, 2013) [8, 10, 11] including organic material, an heterogeneous mixture of bacterias (fungi, algae, bacteria, protozoa, rotifer, nematode) and inorganic materials such as colloids, organic polymers, bivalent ions, salts and dead cells (Chu and Lee, 2004). Various investigators have noticed the enhancing impacts of biofloc technology on resistance to diseases, growth, survival and feed conversion ratio (FCR) of fishes (Azim and Little, 2008; Khanjani *et al.*, 2020; Khanjani *et al.*, 2017) [4, 16, 17].

Among all the species of shrimp, *Litopenaeus vannamei* represent over 90% of shrimp culture in the western hemisphere and presently it is the most commonly cultured shrimp in Central and South American countries, China, India and Thailand (Frias-Espericueta *et al.*, 2001; McGraw *et al.*, 2002; Saoud *et al.*, 2003) [13, 21, 27]. The ability of *L. vannamei* to withstand such an extensive range of salinity helps it being cultured at salinity ranging from 0 ppt to 35 ppt. In India, *L. vannamei* culture is carried out from very low salinities (~0-2 ppt) in Godavari and Krishna districts of Andhra Pradesh and Thanjavur district of Tamil Nadu to very high salinities (50-60 ppt) in Tamil Nadu and Gujarat (CIBA, 2017) [6]. Salinity is one of the most important factors, affecting the growth and survival of Penaeidae family (Kumlu *et al.*, 2000) [18] Although few studies have observed the effects of different salinity levels on growth performance, survival, oxygen consumption, and immune system of *L. vannamei*, the result are controversial (Decamp *et al.*, 2003; Esparza-Leal *et al.*, 2016; Jannathulla *et al.*, 2019; Lin and Chen, 2001; Maica *et al.*, 2012; Wang and Chen, 2005) [9, 12, 15, 19, 20, 28]. Therefore, further efforts are required to optimize the growth and survival of *L. vannamei* at different salinity under the biofloc system.

2. Materials and Methods

The experiment was conducted for 45 days to compare growth and survival of nursery rearing of *Litopenaeus vannamei* post larvae under biofloc at different salinities. The materials used and methodology adopted for present research work is described as following.

2.1 Experimental laboratory

The experiment was conducted at College of fisheries Science, Veraval, Junagadh Agricultural University, District Gir-Somnath, Gujarat. Brine water used for the culture that collected from salt pan located at Victor village, Rajula. The laboratory work was carried out in the college laboratory.

2.2 Biofloc production

Preclianed FRP tanks (7 numbers) of 50 L capacity water used to prepare for biofloc inoculums. Tanks were filled with different seven salinities of water up to 50 L and continuously vigorous aeration was provided by using air blower. The dry pond soil was obtained from shrimp farm of District Surat and Victor village, Rajula. Sugarcane molasses procured from jaggery production factory village Talala was fermented with commercial yeast 24 hour prior to use. Floc inoculums were developed by following methodology of Avnimelech (1999) [3] using 20 gm L^{-1} pond soil, 10 mg L^{-1} ammonium sulphate and 200 mg L^{-1} fermented sugarcane molasses, within 48 hour inoculums were equally transfer in to the experimental tank at the rate of ratio 1:100 (inoculums: water). Carbon source was calculated based on protein contain of feed and quantity of feed used. This was added every twice in week.

Amount of carbohydrate requirement (ΔCH) for assimilate ammonium converted in microbial protein was calculated based on following the standard protocol of Avnimelech (1999) [3] and crab *et al.* (2012) [7]. This is slightly modified based on carbon content of molasses and protein content of feed used. We assumed that in calculation using carbohydrate sources has 50% carbon. To remove 1 g concentration of total ammonia nitrogen 20 g of carbohydrate required (ΔCH) to add in this system to maintain carbon: nitrogen ratio of 15:1

$$\Delta CH = (\Delta N)/0.05 \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

We assumed 50% of feed nitrogen that ammonium (ΔNH_4^+) added in to water by extraction and bacterial decomposition of uneaten feed residue.

ΔN = quantity of feed × % nitrogen in feed × % nitrogen in excretion …….. (2)

Therefore equation of 1 and 2

ΔCH = quantity of feed × % nitrogen in feed × % nitrogen in excretion / 0.05... (3)

In the beginning experimental phase, shrimp PLs were fed 6% of average body weight of feed with 35% of protein. So for 1 kg of shrimp biomass 60gm (21gm protein) of feed is required. However, 16% of protein in feed was assumed to be converted in to nitrogen therefore, with addition of 1 kg feed, 3.36g of nitrogen will be produced out of which 75% (2.52g) of nitrogen dissolve in to the water. Thus, 2.52g of nitrogen is produce from 1 kg of shrimp after giving 60 g of feed. The C:N ratio was maintained at > 15:1 while adding 37.8 g of organic carbon. After 10 day of culture period feeding rate was reduced up to 3% for that calculation was done according to it

2.3 Experimental Animals

Litopenaeus vannamei Post-larvae-12 (PL-12) was procured from "West Coast Frozen Food Pvt Ltd." (Shrimp Hatchery Division), Kotda (20° 41' N, 70° 50') (Ta. Kodinar, Dist: Gir-Somnath). PL were acclimatized and nursed with commercial feed for one day in the 200 L FRP tank. Shrimps PLs were transferred into the tank with different salinities (according to treatment) for acclimatization for 7 days before the start of research. Only healthy and active shrimps of average size 0.021-0.029 gm. were stocked in the experimental tank with and without biofloc. The stocking density of PLs was maintained at one number L^{-1} in tank.

2.4 Experimental setup

The experiment was carried out in square plastic tank of 50 litre capacity. The experiment was set up following a completely randomized design as presented in Table no. 1. Experimental tanks were washed with potassium permanganate solution (5 ppm) and sun-dried before the start

of the experiment. All the tanks were half filled (around 50 L) with water of desired salinity by mixing sea water and brine (Helm and Bourne, 2004) [14]. Tank water was further disinfected by bleaching powder @ 60 ppm and then supplied with 2 air stone-hoses type of diffuser system connected to 0.5 HP blowers for vigorous aeration. Aeration was provided throughout the experimental duration. Zero water exchange system (with intermittent water addition of desired salinity to maintain water volume in all tank) were followed during the whole experimental period of 45 days.

Table 1: Experimental design

Sl. No.	Treatments with biofloc (Salinities in ppt)	Control without biofloc (Salinities in ppt)	Replications
1	10 ppt (T1)	10 ppt (C1)	Triplicate
2	20 ppt (T2)	20 ppt (C2)	Triplicate
3	30 ppt (T3)	30 ppt (C3)	Triplicate
4	35 ppt (T4)	35 ppt (C4)	Triplicate
5	40 ppt (T5)	40 ppt (C5)	Triplicate
6	50 ppt (T6)	50 ppt (C6)	Triplicate
7	60 ppt (T7)	60 ppt (C7)	Triplicate

2.5 Experimental Diet and Feeding
Animals were fed at the rate of 5% of their body weight during the experiment with commercially available feed (CP) having crude protein 35%, crude fat 5%, fiber 4%, and moisture 11%). Feeding frequency was four times a day similar to actual shrimp farm at 07:00 PM (morning), 11:00 PM (morning), 15:00 PM (afternoon), and 7:00 AM (evening).

2.6 Growth Parameters
Randomly 30% of shrimp in every tank were sampled fortnightly for the collection of data required for estimation of growth parameters. The weight of animal was measured by using electronic balance. The utmost care was taken while sampling to minimize stress on the animal. Following growth parameters were estimated-

2.6.1 Growth measurement
$$\text{Average body weight} = \frac{\text{Total body weight of shrimp}}{\text{Number of shrimp}}$$

Mean weight increment = Final average body weight – Initial average body weight

2.6.2 Specific growth rate (SGR)
SGR (specific growth rate) as a percentage was calculated using the formula given below.

$$\text{SGR} = \frac{\text{Log}_e(\text{Final weight}) - \text{Log}_e(\text{Initial weight})}{\text{Number of days}} \text{x}100$$

2.6.3 Food conversion ratio (FCR)
FCR is the weight of the food consumed divided by the body weight gain, all over a specified period of time. The FCR (Food Conversation Ratio) was calculated using the following formula:

$$\text{FCR} = \frac{\text{Amount of feed given (g)}}{\text{Body weight gain(Wet weight)(g)}}$$

2.6.4 Feed efficiency ratio (FER)
The feed efficiency ratio was calculated using the following formula

$$\text{FER} = \frac{\text{Body weight gain (wet weight)(g)}}{\text{Feed given (Dry weight)(g)}}$$

2.6.5 Protein Efficiency Ratio (PER)
Protein efficiency ratio is a measure of utilization of dietary protein. PER was calculated using the following formula.

$$\text{PER} = \frac{\text{Body weight gain (g)}}{\text{Protein fed (g)}}$$

2.6.6 Survival
The survival of the fish was estimated using the following formula

$$\text{Survival (\%)} = \frac{\text{No. of shrimp survived after rearing}}{\text{No. of shrimp stocked}} \text{x}100$$

Statistical analysis of different growth and survival were analyzed by one-way analysis of variance (ANOVA) using SPSS VERSION 23.0. Duncan's multiple range tests was used for post hoc comparison of mean ($P< 0.05$) between different groups. All the data presented in the text, figures and tables expressed are mean ± standard error and statistical significance of the test was set at $P< 0.05$.

3. Results
Forty-five days experiment was carried out to compare the growth performance and survival of *L. vannamei* nursery rearing under biofloc at different salinity. Parameters observed and other results obtained during the experimental period are presented following.

3.1 Growth Parameters
The present study showed better growth performance and yield in biofloc as compared to control. Treatment biofloc showed higher growth performance (ABWG) compared to control. Higher PER, FER, SGR, survival and lowest FCR were found in biofloc treatment compared to control. Detailed result and discussion related to growth performance are presented in the following section.

3.1.1 Average body weight gain (ABWG)
Average body weight gain (ABWG) of *L.vannamei* reared under treatments and control is presented in table-2; 3 and fig 1. *L.vannamei* showed the highest average body weight gain in treatment 30 ppt (3.20±0.666gm) and minimum in treatment 60 ppt (0.76±2 gm). Poor growth of shrimp in control (2.07 ±3.055 gm) maximum and minimum (0.65±4.666 gm) as compared to treatment may be attributed due to under biofloc. There was no significant different ($P>0.05$) was observed in 40 ppt in treatment compared control. There was significant different ($P<0.05$) was observed in 10, 20, 30, 35, 50, 60 ppt in treatment compared control.

3.1.1.1 Growth Performance

Table 2: Growth performance and survival of *L. vannamei* biofloc treatments

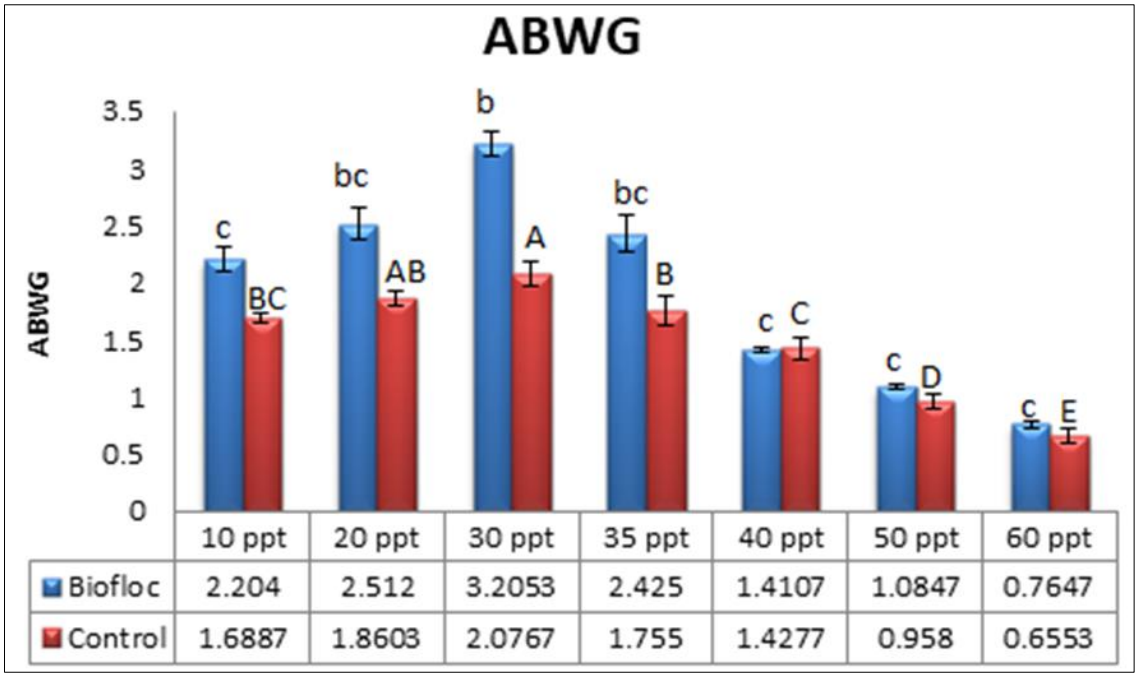
Biofloc	FCR	FER	PER	ABWG	Survival
10 ppt	1.31±0.087^{d}	0.76±0.029^{b}	2.18±0.083^{b}	2.20±0.666 ^{c}	82.66±0.109^{bc}
20 ppt	1.48±0.011^{c}	0.67±0.002^{c}	1.92±0.008^{c}	2.51±0.666^{bc}	85.33±0.135^{b}
30 ppt	1.22±0.003^{d}	0.81±0.001^{ab}	2.32±0.003^{ab}	3.20±0.666^{b}	90.66±0.106^{a}
35 ppt	1.17±0.125^{d}	0.85±0.054^{a}	2.44±0.156^{a}	2.42±0^{bc}	82±0.156^{c}
40 ppt	1.52±0.076^{c}	0.65±0.018^{c}	1.87±0.053^{c}	1.41±0.666^{c}	70.66±0.022^{d}
50 ppt	1.69±0.163^{b}	0.59±0.034^{cd}	1.69±0.097^{d}	1.08±0.666^{c}	54.66±0.015^{e}
60 ppt	1.93±0.044^{a}	0.51±0.006^{d}	1.47±0.019^{d}	0.76±2^{c}	40±0.033^{f}

*Values are presented as mean ± SE

Table 3: Growth performance and survival of *L. vannamei* control

Control	FCR	FER	PER	ABWG	Survival
10 ppt	1.41±0.045^{B}	0.70±0.023^{AB}	2.02±0.066^{AB}	1.68±1.154^{BC}	72±0.052^{A}
20 ppt	1.54±0.092^{B}	0.65±0.040^{ABC}	1.86±0.114^{ABC}	1.86±1.763^{AB}	68.66±0.058^{AB}
30 ppt	1.30±0.0208^{B}	0.76±0.012^{A}	2.18±0.034^{A}	2.07±3.055^{A}	70±0.116^{A}
35 ppt	1.44±0.074^{B}	0.69±0.035^{ABC}	1.99±0.102^{ABC}	1.75±1.154^{B}	66±0.130^{AB}
40 ppt	1.67±0.131^{B}	0.60±0.046^{BC}	1.72±0.134^{BC}	1.42±2.905^{C}	61.33±0.095^{B}
50 ppt	1.73±0.023^{B}	0.57±0.007^{C}	1.64±0.022^{C}	0.95±1.763^{D}	51.33±0.063^{C}
60 ppt	2.94±0.586^{A}	0.36±0.064^{D}	1.04±0.183^{D}	0.65±4.666^{E}	28.66±0.058^{D}

*Values are presented as mean ± SE

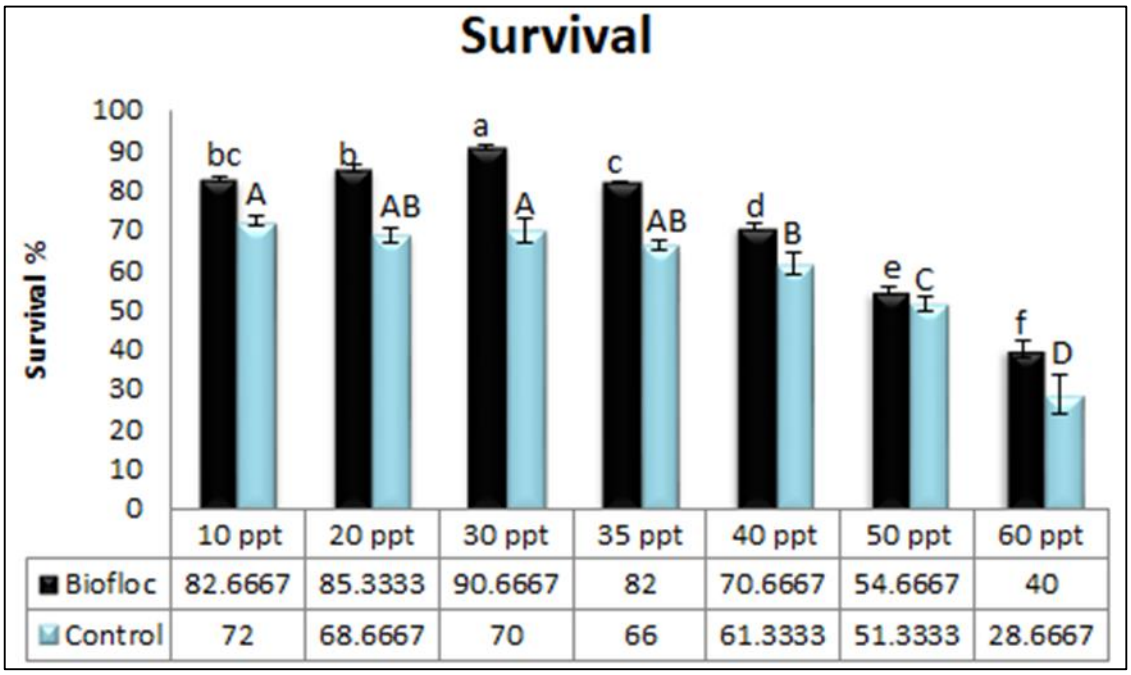


*Values are presented as mean ± SE

Fig 1: Average body weight gain (ABWG) during the culture period

3.1.2 Feed conversion ratio (FCR)

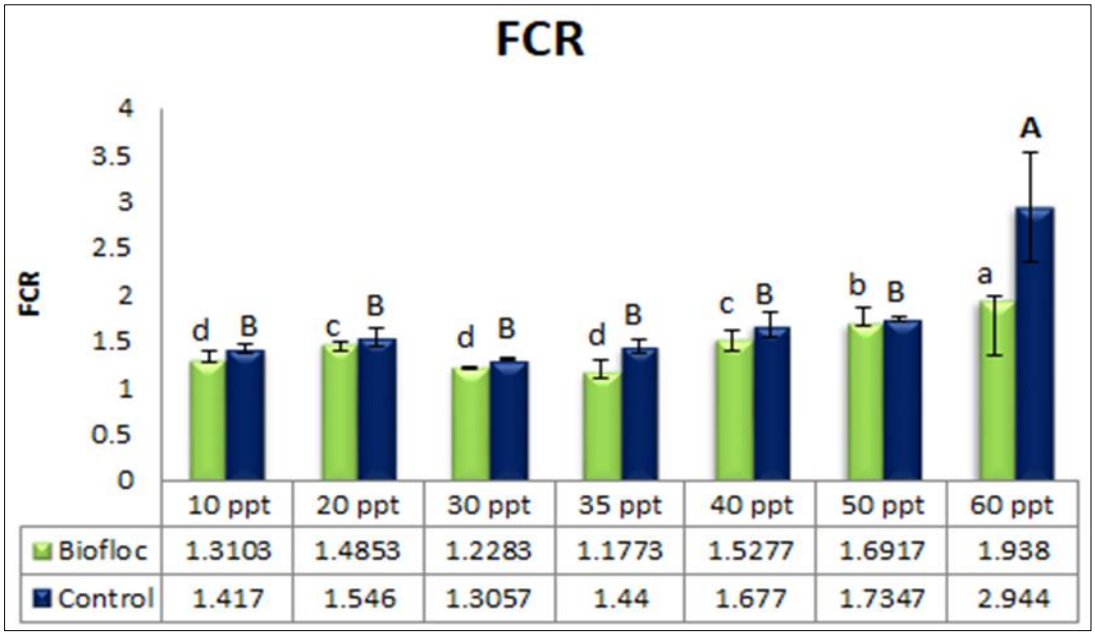
FCR of *L. vannamei* observed in treatments biofloc and control are presented in table-2; 3 and fig. 3. Lowest FCR was found in biofloc treatment 35 ppt (1.17±0.125) & maximum biofloc treatment 60 ppt (1.93±0.044) and control 30 ppt control (1.30±0.020) whereas, maximum in 60 ppt control (2.94±0.586). There is significant different ($P< 0.05$) was found in 10, 20, 30, 35 and 40 ppt biofloc treatment compared to control. There is no significant different ($P > 0.05$) was found in control 50 and 60 ppt compared to other control.



	10 ppt	20 ppt	30 ppt	35 ppt	40 ppt	50 ppt	60 ppt
Biofloc	82.6667	85.3333	90.6667	82	70.6667	54.6667	40
Control	72	68.6667	70	66	61.3333	51.3333	28.6667

*Values are presented as mean ± SE

Fig 2: Survival during the culture period



	10 ppt	20 ppt	30 ppt	35 ppt	40 ppt	50 ppt	60 ppt
Biofloc	1.3103	1.4853	1.2283	1.1773	1.5277	1.6917	1.938
Control	1.417	1.546	1.3057	1.44	1.677	1.7347	2.944

*Values are presented as mean ± SE

Fig 3: Food Conversion Ratio during the culture period

3.1.3 Specific growth rate (SGR)

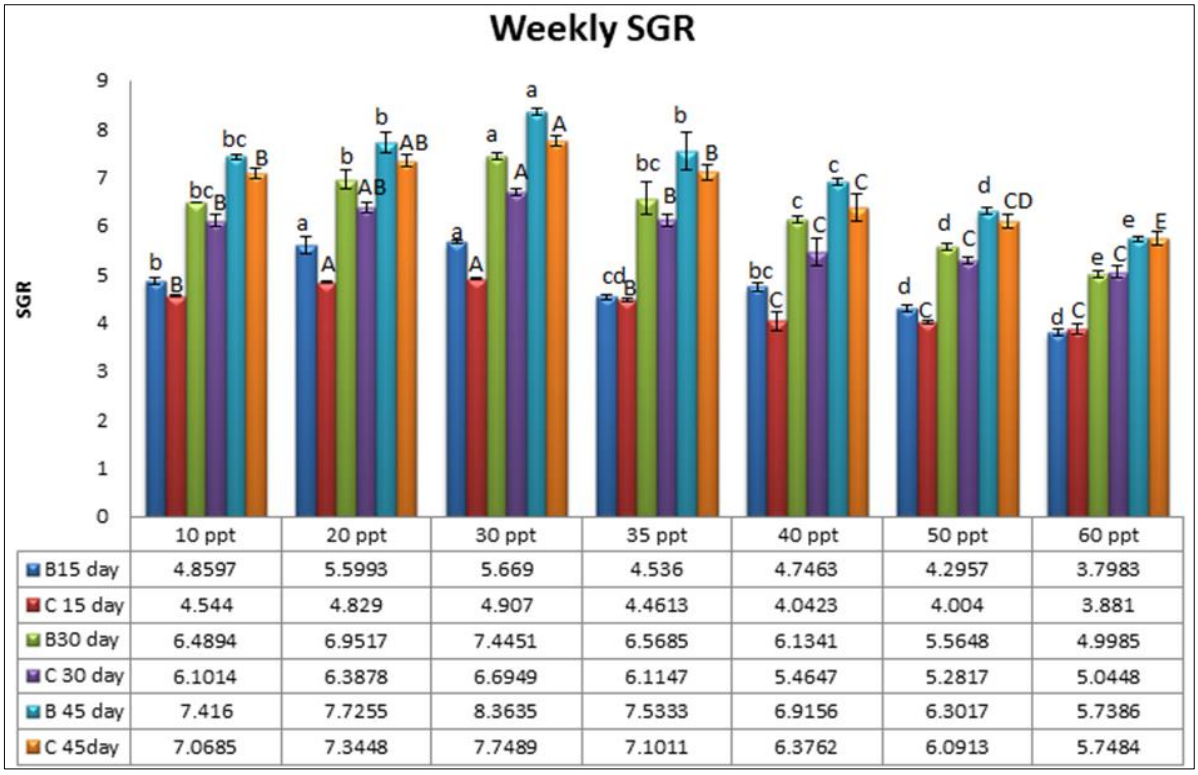
SGR of *L. vannamei* observed in treatments and control are presented in table-4 and fig.4. A significant difference was observed among different treatments and control of *L. vannamei*. The highest SGR recorded was in biofloc treatment 30 ppt (8.36±0.069) and the lowest in 60 ppt (3.79±0.057) and control 30 ppt (7.74±0.090) and the lowest in 60 ppt (3.88±0.105). In present study SGR reported was maximum and minimum in treatment and in control respectively. There is significant different ($P< 0.05$) was found in 10, 20 and 40 ppt (15 day SGR) biofloc treatment in compared to control. There is no significant different (P >0.05) was found in (30-45 day SGR) treatment compared to control. There was significant different ($P< 0.05$) found in 35 and 60 ppt (15 -30 days SGR) biofloc treatment in compared to control. There is no significant different (P> 0.05) was found in (45 days SGR) treatment compared to control. There is significant different ($P< 0.05$) was found in 30 and 50 ppt (15 to 45 days SGR) biofloc treatment in compared to control.

Table 4: Specific growth rate SGR of *L. vannamei* biofloc treatments and control

Biofloc	B-15 day	B-30 day	B-45 day	Control	C-15 day	C-30 day	C-45 day
10 ppt	$4.85±0.057^{b}$	$6.4894±0.009^{bc}$	$7.4160±0.054^{bc}$	10 ppt	$4.5440±0.020^{B}$	$6.1014±0.117^{B}$	$7.0685±0.105^{B}$
20 ppt	$5.59±0.161^{a}$	$6.9517±0.193^{b}$	$7.7255±0.204^{b}$	20 ppt	$4.8290±0.020^{A}$	$6.3878±0.109^{AB}$	$7.3448±0.135^{AB}$

30 ppt	5.66±0.039[a]	7.4451±0.070[a]	8.3635±0.069[a]	30 ppt	4.9070±0.025[A]	6.6949±0.082[A]	7.7489±0.090[A]
35 ppt	4.53±0.055[cd]	6.5685±0.331[bc]	7.5333±0.379[b]	35 ppt	4.4613±0.041[B]	6.1147±0.126[B]	7.1011±0.145[B]
40 ppt	4.74±0.083[bc]	6.1341±0.078[c]	6.9156±0.074[c]	40 ppt	4.0423±0.191[C]	5.4647±0.278[C]	6.3762±0.287[C]
50 ppt	4.29±0.066[d]	5.5648±0.057[d]	6.3017±0.061[d]	50 ppt	4.0040±0.040[C]	5.2817±0.085[C]	6.0913±0.128[CD]
60 ppt	3.79±0.057[d]	4.9985±0.056[e]	5.7386±0.052[e]	60 ppt	3.8810±0.105[C]	5.0448±0.131[C]	5.7484±0.138[F]

*Values are presented as mean ± SE

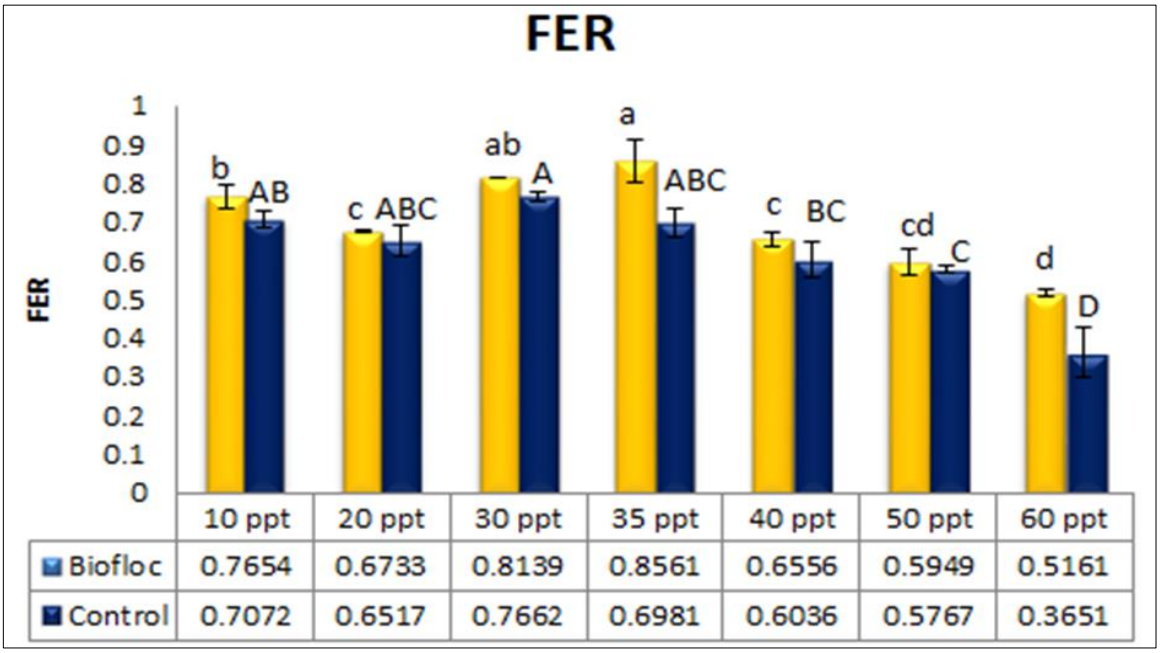


	10 ppt	20 ppt	30 ppt	35 ppt	40 ppt	50 ppt	60 ppt
B15 day	4.8597	5.5993	5.669	4.536	4.7463	4.2957	3.7983
C 15 day	4.544	4.829	4.907	4.4613	4.0423	4.004	3.881
B30 day	6.4894	6.9517	7.4451	6.5685	6.1341	5.5648	4.9985
C 30 day	6.1014	6.3878	6.6949	6.1147	5.4647	5.2817	5.0448
B 45 day	7.416	7.7255	8.3635	7.5333	6.9156	6.3017	5.7386
C 45day	7.0685	7.3448	7.7489	7.1011	6.3762	6.0913	5.7484

*Values are presented as mean ± SE

Fig 4: Weekly variation specific growth rate during the culture period

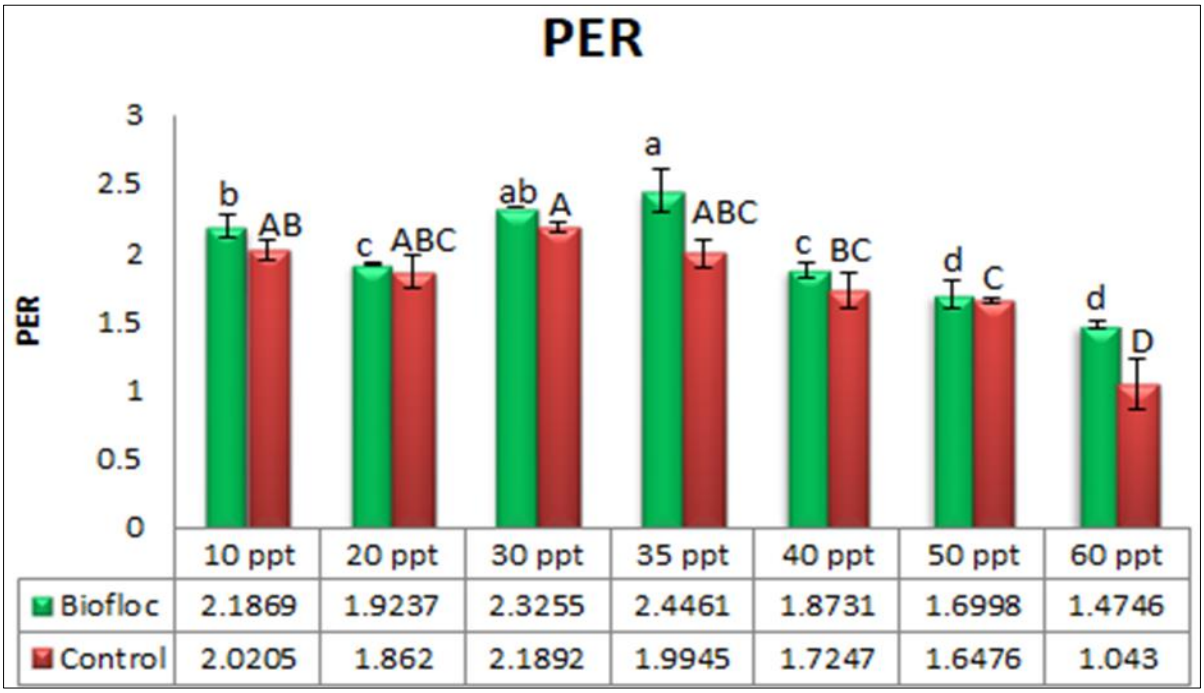
3.1.4 Feed efficiency ratio (FER): FER of *L. vannamei* observed in treatments and control are presented in table-2, 3 and fig.5. It was observed that FER is maximum (0.85±0.054) in biofloc treatment 35 ppt whereas minimum in 60 ppt (0.51±0.006) in treatment and control maximum (0.76±0.012) in 30 ppt whereas minimum in 60 ppt (0.36±0.064) in control. There is significant different ($P< 0.05$) was found in 10, 20, 30, 35, 40 and 50 ppt biofloc treatment compared to control. There is no significant different (P> 0.05) was found in 60 ppt treatment compared to control.



	10 ppt	20 ppt	30 ppt	35 ppt	40 ppt	50 ppt	60 ppt
Biofloc	0.7654	0.6733	0.8139	0.8561	0.6556	0.5949	0.5161
Control	0.7072	0.6517	0.7662	0.6981	0.6036	0.5767	0.3651

*Values are presented as mean ± SE

Fig 5: Feed Efficiency Ratio during the culture period.



	10 ppt	20 ppt	30 ppt	35 ppt	40 ppt	50 ppt	60 ppt
Biofloc	2.1869	1.9237	2.3255	2.4461	1.8731	1.6998	1.4746
Control	2.0205	1.862	2.1892	1.9945	1.7247	1.6476	1.043

*Values are presented as mean ± SE

Fig 6: Protein Efficiency Ratio during the culture period

3.1.5 Protein efficiency ratio (PER)

PER of *L. vannamei* observed in treatments and control are presented in table-2, 3 and fig.6. It was observed that PER is maximum (2.44±0.156) in biofloc treatment 35 ppt whereas minimum in 60 ppt (1.47±0.019) in treatment and control maximum (2.18±0.034) in 30 ppt whereas minimum in 60 ppt (1.04±0.183) in control. In the present study, PER was maximum in treatment 35 ppt (T5) and C30 30 ppt control. There is significant different ($P< 0.05$) was found in 10, 20, 30, 35, 40 and 50 ppt biofloc treatment compared to control. There is no significant different ($P > 0.05$) was found in 60 ppt treatment compared to other control.

3.1.6 Survival

Survival of *L. vannamei* reared under biofloc treatment and control is presented in table-2 and 3, figure 2. Survival of *L. vannamei* at the end of the experiment was maximum in biofloc 30 ppt (90.66±0.106) and lowest in the 60 ppt (40±0.033) and in control maximum 10 ppt (72.66±0.052) and minimum 60 ppt (28.66±0.058) respectively. There is significant different ($P< 0.05$) was found in 30 ppt biofloc treatment compared to control. There is no significant different ($P > 0.05$) was found in control 10, 20, 35, 40, 50 and 60 ppt compared to other control. In the present study maximum survival rate was 90.66% in the 30 ppt treatment higher than 72% control 10 ppt and minimum was 40% in biofloc 60 ppt treatment & 28.66% control 60 ppt.

4. Discussion

Shrimp was highest grow in 30 ppt. it was similar (Maica *et al.*, 2012) [20] they revealed that salinity increase 25 ppt highest weight gain observed compared to lower salinity 10 ppt and 20 ppt. similar reported growth was decreased at higher salinities reported by Zhu *et al.* (2004) [30] they reported poor growth performance of *L. vannamei* juveniles at higher salinity. This result is in agreement with the finding of several researchers (Menz and Blake, 1980; Pante, 1990; Bray *et al.*, 1994; and McGraw *et al.*, 2002) [22, 24, 5, 21]. Bray *et al.* (1994) [5] reported that the salinity below the isosmotic point *L. vannamei* grows the better. The results obtained in our experiment showed that *L. vannamei* growth performance in treatment was comparable with control with significant difference. According to Khanjani *et al.* (2020) [17] the better growth rate, average body weight gain, specific growth rate and survival rate were remarked in 32 ppt salinity. The report of high mortality in 60 ppt treatment and control was in agreement with the finding of Zhu *et al.* (2004) [30] as they demonstrated that a high Na/K ratio in seawater resulted in poor survival of *L. vannamei* and same was supported by the finding of Perez-Velazquez *et al.* (2007) and Palafox *et al* (1997) [26, 23] *i.e.* if salinity increase survival rate is decrease. Shrimp mortality was affected by salinity, especially when it was decrease from 30 and 35 ppt. Esparza-Leal *et al.* (2016) [12]. The highest levels of survival rate were observed at 32 ppt. Khanjani *et al.* (2020) [17] which is similar to our experiment to our result. Best average body weight gain and survival was observed in 20, 30, and 35 ppt. in biofloc treatment compared to control. Food conversion ratio is better observed in biofloc compared to control. It may be due to ideal salinity better FCR was observed in 30 and 35 ppt compared to other salinity. Second best FCR was found in 10 and 20 ppt. Higher FCR was 40, 50 and 60 ppt salinity due to higher salinity. The highest levels of SGR were observed at 30 and 35 ppt. which is similar to our experiment to our result Khanjani *et al.* (2020) [17]. The SGR obtained results may be due to inclusive effects of biofloc and salinity. According to Yan *et al.* (2007), SGR decreases with increase in salinity 35 ppt to 60 ppt. The highest feed efficiency ratio was observed in shrimps at 30 and 35 ppt. salinity in biofloc. The highest protein efficiency ratio was observed in shrimps at 30 and 35 ppt. salinity in biofloc. In biofloc best PER found in different salinity compared to control. In biofloc best FER found in different salinity compared to control. The lower salinity level shrimp were remarked highest feed conversion ratio and the lowest feed efficiency.

5. Conclusions

In conclusion, it can be said that biofloc based culture is very

well suitable for *L. vannamei* at different salinity. *L. vannamei* performance under biofloc was better at 20, 30 and 35 ppt compared to control. In addition, biofloc shows better effect at salinity 20, 30 to 35 ppt as compared to control. Hence farmers can be recommended under biofloc to maintain a salinity of 20, 30 and 35 in the pond for a better harvest.

6. References

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