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Differentiating the Economics, Profitability, Growth performance and Viability of Litopenaeus vannamei, in a newly designed system titled Semi-Recirculating Aquaculture system with the Conventional Normal Biofloc System

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ABSTRACT

This research compares a traditional Biofloc system to a Semi Recirculatory Aquaculture Biofloc system. The latter like the conventional Biofloc system, follows the same culture pattern, with the exception of a recirculatory mechanism integrated into the culture process, which could cause considerable differences. For this study, we chose two farms in Kerala's Ernakulam district: Kodungaloor and Aroor, which use Semi-RAS and normal Biofloc systems, respectively. Water quality indicators, cultured species productivity, 70-day FCR ratios, disease frequency, feed intake intensity, TSS and TDS, feed digestibility, investment, and profit percent in both culture farms were examined from day one to day thirty. Dissolved oxygen levels were 7 ppm and 5 ppm, ammonia levels were 0 ppm and 1 ppm, TDS-TSS levels were 50-100 ppm and >200 ppm in Semi RAS and biofloc systems, respectively. On the 30th day of the culture phase, according to the data, Semi-RAS yielded 3.6kg/m3, while biofloc yielded 1.6kg/m3. Stress and microbial contamination were reduced in Semi RAS, while digestibility increased. Although the Semi RAS system costs more than Biofloc, farmers that use it can earn three times as much and have a greater profit percentage. According to our findings, Semi RAS technology offers aquaculture farmers more possibilities.

KEYWORDS

Semi RAS system, Biofloc, Water quality, Aquatic Health, *Litopenaeus vannamei*, Digestibility.

Introduction

Aquaculture growth over the past few decades has sparked a demand for novel, environmentally benign, and economically viable fish-culturing methods (R Crab, 2012). Recirculating systems (RAS) and biofloc technology (BFT) have been developed as efficient substitutes for conventional fish rearing systems (such as fish farming in ponds) to decrease water usage and increase productivity. BFT was primarily established in regions where access to water and/or land posed significant limitations to the expansion of aquaculture production. In addition to treating feeding wastes, this method could also give fish or crustaceans access to some essential nutrients. Additionally, BFT offers a dense and active bacterial population that improves the treatment of organic wastes and, in turn, recycles critical nutrients since it operates with minimal water exchange (0.5–1% per day). A flow-through system called Semi-RAS Biofloc Technology uses a moving bed bioreactor for water exchange, which performs the same function as the floc in BFT (C Li, 2019). In our study, we compared the growth performance of *Litopenaeus vannamei*, the Pacific white leg shrimp, in both systems. Since the late 20th century, *L. vannamei* culture has gained a good amount of popularity. Many farmers could make a quick and considerable amount of profit with shrimp farming because of its intensification (Pinto, 2020). The species sensitivity to a number of diseases, including the virulent white spot syndrome, vibrio infection, and other diseases, limits the productivity (Lightner,2011). For farmers, the former hurdles in shrimp farming resulted in significant financial losses to the tune of 50% to even 100% (Kalaimani,2013). Due to the effluent discharge from contaminated farms, the popularity of cultivating *L. vannamei* has also contributed to the development of infectious diseases. BFT is an advanced method that is widely used for shrimp culture, particularly for *L. vannamei*. Biofloc is an agglomerate of various microbial communities, which include algae, bacteria, and other organic matter (Y Avnimelech,2009). Biofloc is a zero-water exchange system, is being employed by utilising the C/N ratio to convert the toxic nitrogenous compounds into useful proteins and thereby maintaining the water quality in a scientific manner (WJ Xu,2016). By ensuring proper management of water quality parameters, it enhances the health condition of the cultured species as well as their nutritional status that results in increased growth and survival rates to the tune of 50% compared to the traditional system (M.H Khanjani,2020). But since it's a zero-water exchange system, there are certain concerns that are being constantly faced by the farmers, including various disease invasions. This prompted the farmers to adapt a new culture technique that amalgamated both the biofloc technology and the recirculating aquaculture technique, termed "Semi-RAS Biofloc Technology (Semi-RAS BFT)." Semi-RAS BFT is a flow-through system that utilises the moving bed bioreactor for water exchange that serves the same function as the floc in BFT does. It performs the water treatment functions such as BOD and COD removal as well as nitrification and denitrification processes (M.G.C Emerenciano,2017). The flow rate of the effluent moving out of the system is equal to the flow rate of the influent flowing into the system. It consists of bio media, which facilitates the bacteria's growth in multiple layers. The bacteria digest the organics in the waste materials and convert the insoluble materials into biomass, which is then removed by a soil separation system by moving it downstream. It is an aerobic system that introduces oxygen into the system by using venturi tubes and microbubble injectors. The continuous movement of media created in the tank reduces the deposition of suspended solids in the tank, which could cause any head loss. The ammonia required for the nitrification process can be easily obtained from fish excreta, ensuring the system's efficiency. It's a raceway system with narrow, long D-shaped tanks where constant circulation happens and no coagulation takes place. This system consists of a main tank, a settling tank, and biofilters, which play a major role in producing clear water within the system. Water quality parameters are constantly maintained, and oxygen availability is higher as it is a flow-through system. In this context, the purpose of our research is to compare the growth performance, culture efficiency, and economic efficiency of *L. vannamei* in Semi-RAS BFT and Normal BFT. In this context, the purpose of our research is to compare the growth performance, culture efficiency, and economic efficiency of *L. vannamei* in Semi-RAS BFT and Normal BFT.

MATERIALS AND METHODS

STUDY SITE

This study was conducted in two locations of Kerala, Aroor and Kodungaloor, where the biofloc and semi-RAS culture techniques are used, respectively. Both the sites are lying in the same meteorological and environmental profile**.**

FISH ACCLIMATION

The seeds for the culture were purchased from the Jay Jay Aqua Tech, Pondicherry, India.The fish were fed a commercial diet ie 35% protein, 4% fat, and 6% ash (Christian Larbi Ayisi, Jinliang Zhao, 2017) four times per day at 3% of their total body weight during two weeks in 2,000-L circular tanks filled with approximately 1,600 L of dechlorinated tap water. The tanks were continuously aerated while maintaining a constant water temperature of 25 ± 1°C and a 12-hour light/dark cycle. A daily interchange of about 50% of the water volume took place.

Design

Normal Biofloc system

The biofloc culture system included 10 circular tanks of diameter -4 m, depth- 1.5 m, with a 25:1 slope towards the centre. The system was stocked with shrimp species at a stocking density of 250/m^3. Each unit must have an effective water volume of 100 m^3, a floc density of 10^6–10^9 nos/cm^3, and a floc size that varies from 100–250 micrometres. Aeration points are made with aeroxy tubes in the form of rings at the bottom sector, and the air is supplied at a rate of 5 litres per minute. Sufficient air pumps or blowers are being provided along with an automatic generator of 60KV to avoid power loss. The floc has been prepared by selecting suitable carbon sources like jaggery and mixing it with the dried pond soil by providing vigorous aeration.

Semi-RAS BFT

The Semi Recirculating BFT consists of a main tank, settling tank and biofilters. The *L. vannamei* has been stocked at a density of 250 m^3. The influent flows from the main tank to the equalisation tank, which performs the function of removing the suspended solids, and later it moves towards the Moving Bed Biofilm Reactor (MBBR)tank 1 and 2, which consist of bioreactors (MBBR media) that perform the function of BOD-COD removal as well as nitrification and denitrification processes. Bleaching has been done at the rate of 5 ppt chlorine followed by the dichlorination process continuously for 3 days with proper aeration. The settled particles were removed by using a one-micron net. Aeration has been done with the support of venturi tubes, which act as microbubble injectors. Water flow is constantly maintained all through the system, and aeration is done at 7 mg/L.

FISH REARING

The species in all three systems have been supplied with floating pellets on which the pellet size and protein concentration change with the size of the fish. The biochemical composition of the feed was moisture (max) 11%, crude protein (min) 43–44%, crude fat (min) 7%, crude fibre (max) 3%, ash (max) 16%, and lysine (min) 1.2%. The fish were fed at 7 hrs. and 17 hrs. twice a day.The experiment was carried out for 4-6 months.

ANALYTICAL METHODS

WATER QUALITY PARAMETERS

Water quality parameters have been measured by using mercury thermometers for temperature, Winkler's method for dissolved oxygen, an API ammonia test kit for ammonia, a pH metre for pH, a refractometer for salinity, and a sechii disc for water transparency

GROWTH PERFORMANCE

At 2-week intervals, about 25 samples were taken, and their length and weight measurements were taken using a ruler and an electronic weighing balance, respectively. Using the data obtained, various growth indices have been calculated, including the feed conversion ratio, survival rate, specific growth rate, daily weight gain, and condition factor.

Survival ratio= $100 \times \frac{FINAL\ NUMBER\ OF\ FISH}{INITIAL\ NUMBER\ OF\ FISH}$

Condition Factor = $100 \times \frac{wf}{l^3}$, w= final weight of fish, l= final length of fish

FCR= $\frac{\text{Total feed intake of fish (g)}}{\text{body weight increment (g)}}$

DWG (g/day) = $\frac{W2 - W1}{T2 - T1}$, W1 = fish weight (g) at time period T1, W2 = fish weight (g) at time period T2.

Specific growth rate (SGR)= $100 \times \frac{\ln wf - \ln w}{T}$, W_i = wet weight at the end of the experiment (g), W_f = wet weight at the start of the experiment (g), T = experimental period (day) and ln = natural logarithm

ECONOMIC EFFICIENCY

The techno-economic efficiency of the biofloc systems were analyzed using different indicators such as total capital cost (Rs.), annual fixed cost (Rs.), operating cost for two cycles (since two cycles each of five months were possible annually) (Rs.), total annual cost (Rs.), subsidy component (Rs.), total harvest (kg), total returns (Rs.), net profit (Rs.), benefit cost (B:C) ratio, and rate of return on investment.

STATISTICAL ANALYSIS

Data analysis was conducted using SPSS software (version 16.0) and R packages of factoextra and FactoMineR. Kolmogorov–Smirnov test was used to assess the data normality and homogeneity. Significant differences were determined through t test, followed to compare the differences between the BFT and Semi-RAS BFT. Differences were considered statistically significant when $p < .05$. All findings are presented as the mean ± standard error (mean ± SE).

RESULTS

WATER QUALITY

Water quality parameters in both systems were compared, and it was found that there is a significant difference in the magnitude of parameters in the SEMI RAS and Biofloc systems. The DO level in the semi-recirculating system was maintained at 7 mg/l all through the culture period, while in the biofloc system there is a significant fluctuation in the level of dissolved oxygen (4–6 mg/l). The water temperature in both systems was between 27 and 28 degrees Celsius. The pH in the semi-RAS system didn't show much fluctuation from the beginning to the harvest, and it existed at a level of 6-7.5. In a typical biofloc system, the pH level drops significantly during the culture period. It was about 6 at the beginning, but gradually decreased and reached a lower value (about 4) in the 14th week. Salinity was maintained at 15 ppt and 16 ppt in the semi-RAS and normal biofloc systems, respectively. The ammonia content in the semi-RAS system didn't exceed an amount above 0.5 ppm, while in normal biofloc it showed a gradual increase from 1-4 ppm during the culture period. The water's transparency decreased considerably in normal biofloc compared to the semi-RAS system.

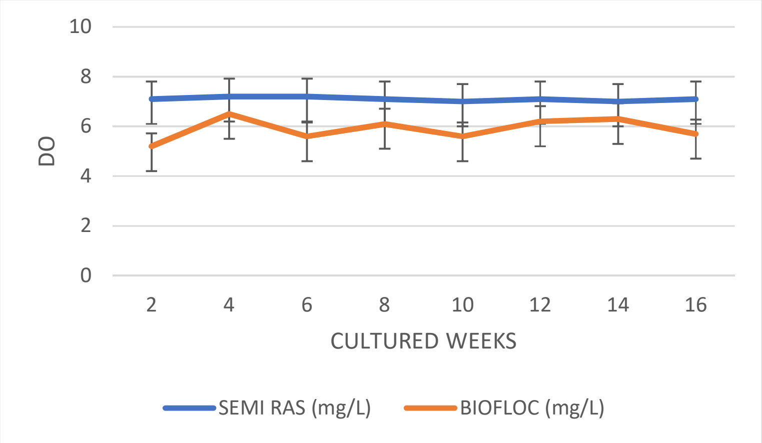

Fig 1: Total Dissolved Oxygen levels in mg/L in Semi RAS System and Biofloc system for L. Vannamei of stocking density 250/ m³

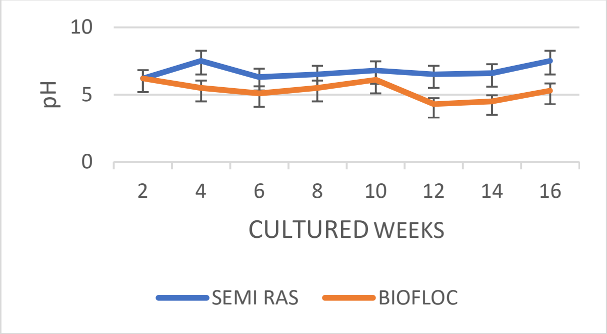

Fig 2: pH levels in Semi RAS System and Biofloc system for L. Vannamei of stocking density 250/ m^3

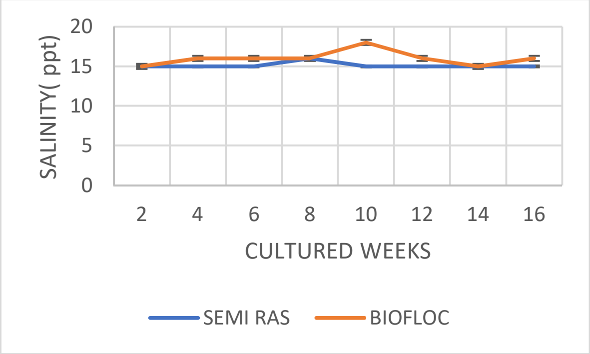

Fig 3: Salinity levels in ppt in Semi RAS System and Biofloc system for L. Vannamei of stocking density 250/ m^3

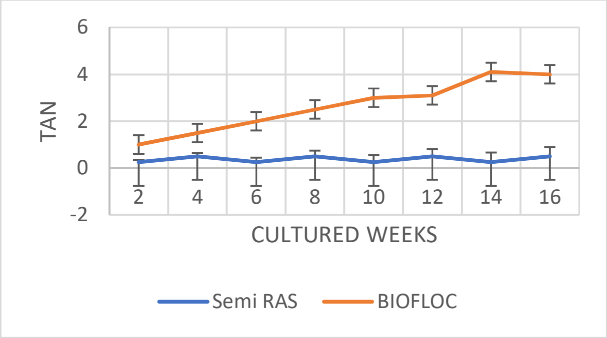

Fig 4 : TAN levels in mg/L in Semi RAS System and Biofloc system for L. Vannamei of stocking density 250/ m^3.

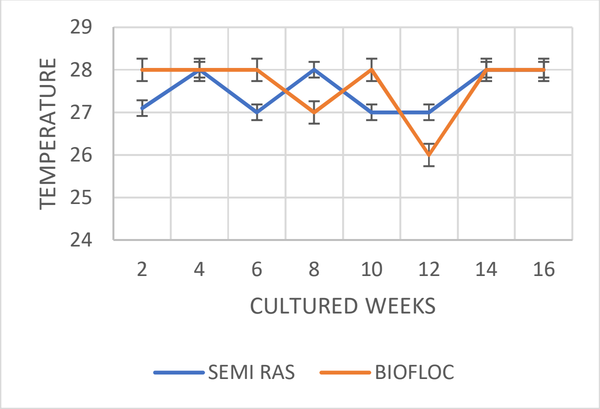

Fig 5: Temperature levels in degree celsious in Semi RAS System and Biofloc system for L. Vannamei of stocking density 250/ m^3.

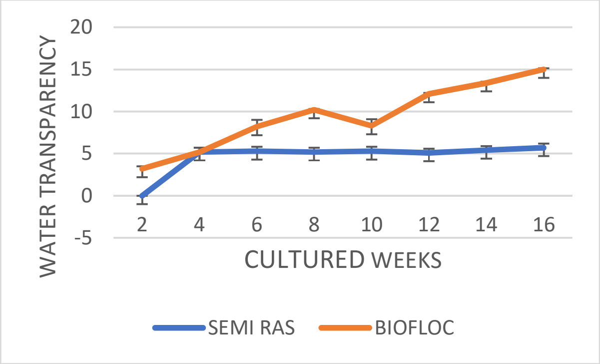

Fig 6: Water transparency levels in in Semi RAS System and Biofloc system for L. Vannamei of stocking density 250/ m^3.

GROWTH PERFORMANCE

The growth performance in both systems was compared on the basis of the total weight and length of the species obtained in both culture systems. In general, the growth rate in the semi-RAS is found to be higher compared to the normal biofloc system. The growth rate in both systems showed a linear increase from the first week to the 16th week. The daily weight gain in grams (DWG) of semi-RAS was found to be greater than that of biofloc. Similarly, the specific growth rate as well as the average daily weight gain are higher in the Semi-RAS system. The increase in length of the species in both systems has also shown a similar pattern.

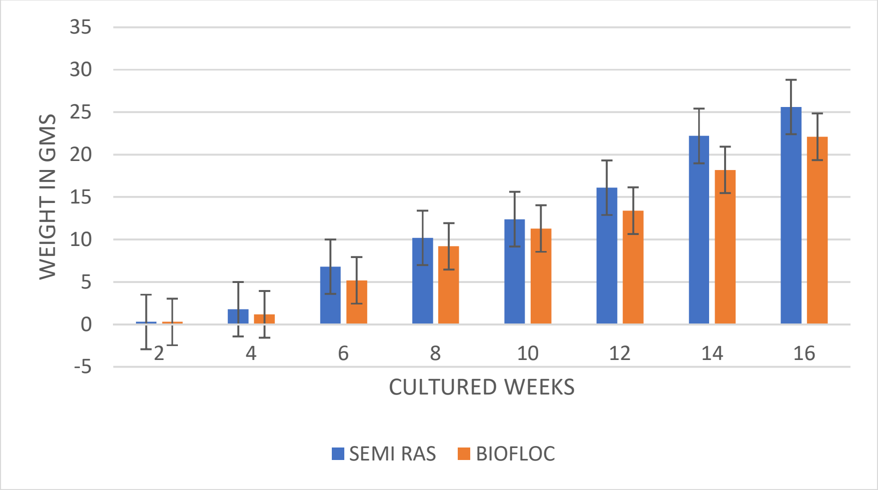

Fig 7: Growth performance of *L.Vannamei* in Semi RAS and normal biofloc system in terms of weight in grams of stocking density 250/ m^3.

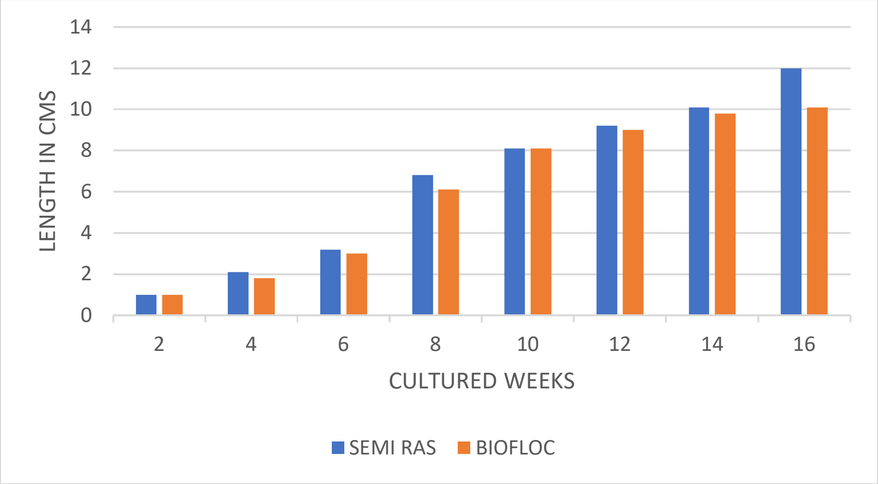

Fig 8: Growth performance of *L.Vannamei* in Semi RAS and normal biofloc system in terms of length in cms of stocking density 250/ m^3

TABLE 1: Growth performance of L.Vannamei in Semi RAS and Normal biofloc system

Parameters	Semi RAS	Biofloc
Initial length	1.1 mm	1.1 mm
Initial weight	0.3 gm	0.3 gm
Final length	12 cm	10 cm
Final weight	25.6 gm	22.1 gm
Average Daily Weight Gain	0.22 gm/day	0.19 gm/day
Specific Growth Rate (%)	22%	19%

$$\text{Average Daily Weight Gain} = \frac{\text{Final Weight} - \text{Initial Weight}}{\text{Days}}$$

$$\text{Specific Growth Rate} = \frac{\text{Final Weight} - \text{Initial Weight}}{\text{Days}} * 100$$

FEED CONVERSION RATIO (FCR)

The feed conversion ratio of the biofloc system was found to be higher than that of the Semi-RAS system. The average feed intake is greater in normal biofloc. The total consumed feed and the total harvested fish biomass in Semi-RAS are in the ratio 1:1, and the FCR is 1. While in normal biofloc, the amount of total feed consumed is higher than the total harvested fish biomass, and thereby the FCR is 1.3.

Table 2: Feeding efficiency of *L.Vannamei* in Semi RAS system and normal biofloc system

Parameters	Semi RAS	Biofloc
Total stocked fish(nos/m^3)	250/m^3	250/ m^3
Total harvested fish biomass(kg)	5 kg/ m^3	3kg /m^3
Total consumed feed (kg)	5 kg/ m^3	4 kg/ m^3
Feed conversion ratio	1	1.3

FCR = Total used feed / Total weight of shrimp harvested per m3.

SURVIVAL RATE

The species in the semi-RAS system have shown a better survival rate compared to the normal biofloc system. Even though the stocking density is the same in both systems, due to the higher survival rate in the former, the Semi-RAS system resulted in the highest extrapolated yield. The condition factor of Semi-RAS is higher than that of normal biofloc. A higher coefficient of variation for length and weight was expressed in the semi-RAS system compared to normal biofloc.

Table 3: Culture efficiency and biometric indices of harvested shrimp in Semi RAS system and normal biofloc system.

Parameters	Semi RAS	Biofloc
Yield obtained/ m^3	5kg/ m^3	3 kg/ m^3
No; of fishes survived	22150	19325
Survival ratio %	88.6 %	77.3%
Condition factor -K	0.0148	0.0214
CV of final length (%)	11 cm	10 cm
CV of final weight (%)	25.6 gm	22.1 gm

The survival ratio = <u>No of fishes survived</u> * 100

Condition factor K = 100 * W/L3, W = fish weight (g) and L = total length (cm)

ECONOMIC EFFICIENCY

The economic efficiency of the two systems was compared at the same stocking densities. The fixed costs, variable costs, revenue, and profit obtained from both systems were analysed. We reached at a conclusion that Semi RAS system showed better economic efficiency than normal biofloc.

BIOFLOC FINANCIALS

Table 4: Finance details of normal biofloc system

SL no	Particulars	Unit rate (Rs)	Quantity	Amount (Rs)
	INFRASTRUCTURAL DEVELOPMENT COST			
1	Biofloc tank (2-8 tanks having a total volume of 100 m3)			1,56,000
2	Water pump 1/2hp	4,000/ no.	1	4,000
3	Blower (2hp) or equivalent	17,000/ no.	3	51,000
4	Venturi pump 370 w (470l/m)	8,000/ no.	2	16,000
5	Generator (Automatic 5-7 KV)	2,00,000/ no.	1	2,00,000
6	Roofing (UV resistant PVC sheet and supporting measures]		LS	1,50,000
7	CCTV	12,000/ no.	1	12,000
8	Electronic weighing balance (Min 10 kg)	5,000/ no.	1	5,000
9	Biofloc cone			1,200
10	Nets, Utensils	2,000/ set	1 SET	2,000
11	Plumbing, airline & air points		LS	24,000
12	Electrification & lighting		LS	24,000
13	Name board (Metal)	4,000/ no.	1	4,000
14	Contingency			800
	SUB TOTAL (A)			**6,50,000**
	OPERATIONAL COST			
1	Vannammei shrimp seed SPF(PL 12- 14) @ 250/m3	40paise/no	25000 nos	10000
2	Feed, 24-32% protein	Rs 100/kg	1000 kg	100000
3	Chemicals, Medicines, Probiotics		LS	12000
4	Carbon sources	50/kg	500 kg	25,000
5	Fuel & electricity		LS	28,000
6	Water quality test equipment	7,000/ no.	1 no	7,000
7	Contingency			3,400
	Sub total (B)			**185400**
	Grand total			**8,35,400**
	RETURNS IN FOUR MONTHS			
1	300 kg/ 4 months	400 /- per kg	1,20,000	
2	operational cost	618/kg	1,85400	
3	Profit in 4 months	251.36/kg	65400	

SEMI RAS FINANCIALS

Table 5: Financials of Semi RAS system.

SL. No.	Item name	Quantity unit	Price per unit	Amount
1	12 m dia frame with 1 " square tube ¾ " square and 8 mm tmt bar	1 nos	90000	90000
2	12 m dia 700/750 gsm srf nylon sheet(1.5 m)	1 nos	66000	66000
3	1.5 hp regenerative blowers	2 nos	24800	53000
4	Aeroxy grid with 40 m aeroxy tube	1 nos	12000	12000
5	Aeration and plumbing material(supreme)	1 nos	20000	20000
6	Roofing with 2" and 1.5" gi pipe and 200 gsm nylon sheet (full covered)	1 nos	150000	150000
7	Settling tank(waste management)1000 ltr	1 nos	16500	16500
8	Sun sun JTP 10000 water pump	1 nos	5000	5000
9	6 mm blk poly foam sheet for protection	65 m	70	4550
10	Black sheet for ground protection	60 nos	65	3900
11	installation , labor and transportation	1	25000	25000
12	Generator	1	70000	70000
13	Contingency		10000	10000
			Total	525950
	OPERATIONAL COSTS FOR 4 MONTHS			
1	Vannammei shrimp seed SPF(PL 12- 14) @ 250/m3	40 paise/ no.	25000 no.	10,000
2	Feed, 24-32% protein	100 Rs/kg	500 kg	50000/-
3	Chemicals, Medicines, Probiotics		LS	12,000
4	Fuel & electricity		LS	28,000
5	Water quality test equipment	7,000/ no.	1 no	7,000
6	Contingency			10000
	Sub total (B)			**117000**
	Grand total			**6,42,950**
	RETURNS IN 4 MONTHS			
1	500 kg per 4 month	400 /- per kg	2,00,000	
2	operational cost	234/kg	1,17,000	
3	Profit in 4 months	251.36/kg	**83000**	

DISCUSSION

The water quality parameters in the semi-RAS system have given better results compared to the normal biofloc system due to its recirculating pattern of culture. As the former system followed a flow-through culture technique, the accumulation of TDS and TSS was comparatively much less. Since the Semi-RAS system uses microbubble injectors like venturi pipes, the concentration of dissolved oxygen has been maintained at a higher level from the beginning until the harvesting of the culture. The flow-through, recirculating nature of the system also contributed significantly to enhancing the DO level compared to the normal biofloc system, which follows a stagnant nature. Due to the higher availability of DO, the feed utilisation efficiency of the cultured species was higher in Semi-RAS, and as a result, the feed accumulation rate was lower. This has had a positive effect on the system's total ammonia nitrogen level. Along with this, the flow-through nature of the system has made a significant contribution to reducing the TAN. While the normal biofloc system uses the flocs that are being grown within the system, the MBBR technique used in the Semi-RAS biofloc system plays a major role in enhancing the water quality. So the flow through the recirculating nature of the biofloc system in Semi-RAS helps to improve the culture efficiency by enhancing the water quality parameters. When dissolved oxygen becomes the priming limiting factor and unionised ammonia becomes the primary limiting metabolite, the importance of regulating water quality parameters during fish culture increases. The total ammonia nitrogen was reduced considerably, and the DO level was enhanced. This has resulted in a significant increase in the C:N ratio in the semi-recirculating system, reducing the occurrence of pathogenic bacteria that affect human health as well as the growth of cultured species to a large extent. As a result, the health of the shrimps in the semi-RAS system was discovered to be much better, with less pathogen invasion. Because the semi-RAS system maintained a strict salinity range compared to normal biofloc, the invasion of halophilic pathogenic bacteria like V. parahaemolyticus was significantly reduced. As the ammonia level in the Semi-RAS system has been maintained in lower ranges all through the culture period, the requirement of floc density is less compared to normal biofloc for maintaining a higher C:N ratio. Since the floc required for the culture is being maintained outside the system in a semi-RAS, it has given positive results including reduced TAN, low organic matter content, and higher water transparency due to the optimum level of total dissolved solids, total suspended solids, etc. Even though the stocking densities are similar in both systems, the final weight, DWG, and SGR of species are higher in Semi-RAS due to better maintenance as well as an effective mode of operation and culture technique. The higher value of the condition factor in the semi-RAS system indicated that the particular system had provided better conditions that facilitated optimum feeding, a disease-free environment, and various physiological factors compared to the normal biofloc. Due to the increased availability of dissolved oxygen, the FCR in the semi-RAS system was reduced, which resulted in an increase in overall fish production. Increased DO has also helped to a great extent to reduce ammonia and nitrite toxicity. The higher survival rate of the cultured species in the semi-RAS system resulted in a higher yield. The economic efficiency of the two systems is an essential criterion to be compared. Because the Semi-RAS system employs the MBBR technique, the carbon source requirement is much lower than in a traditional biofloc. As a result, the fixed and operational costs of a standard Biofloc system have risen by 17.55% and 40.25%, respectively, when compared to the Semi-RAS system.

CONCLUSION

Through our study, we have reached the conclusion that the semi-recirculating aquaculture biofloc system is more profitable as well as efficient than the normal biofloc system. Due to its recirculating flow through nature, the Semi-RAS system can effectively maintain the water quality parameters and thereby increase the growth, reduce disease susceptibility, decrease the chances of disease invasion, and improve the health status of the cultured species. So, we can conclude that the newest semi-RAS system should be made popular among the common farmers, which could improve their farming in a profitable way.

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