Received : 26.10.2022 | Accepted : 12.12.2022 | Online published : 16.12.2022
https://doi.org/10.54986/irjee/2022/dec_spl/317-322

IRJEE SOCIETY OF EXTENSION EDUCATION

RESEARCH ARTICLE

Bio-economic Evaluation of Biofloc Based Rohu (Labeo rohita) Culture System

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ABSTRACT

Biofloc technology is based on the assimilation of inorganic nitrogen species (ammonia, nitrite and nitrate) by the microbial community present within the water body. The objectives of the present study were to determine the effect of biofloc process on the growth and production of rohu (Labeo rohita) reared at different stocking densities in tank culture and to evaluate economics of the different treatments. The experimental design included three biofloc treatments (with three replications) and three controls (with three replications): biofloc tank fed with 20 per cent crude protein feed and extra carbohydrate and control tank fed with 30 per cent crude protein feed at three different stocking densities, viz., 1.3, 2.6 and 3.9 number fingerlings per m^2 of surface area of tank. The fish were cultured for a period of three month. It can also be observed that at higher stocking density average weight of fish decreased. This is because at higher stocking density, fish experiences more stress due to overcrowding and competition for feed. In case of biofloc treatment at low stocking density, average fish growth was higher as compared to other treatments. Specific growth rate (SGR) and protein efficiency ratio (PER) were highest and feed conversion rate (FCR) was lowest for biofloc treatment with lowest stocking density of 1.3 nos/m^2. The economics of the different treatments were assessed by their internal rate of returns (IRR). Equivalent Uniform Annual Worth (EUAW) was evaluated for the different treatments as the treatment units had components of different life spans. The internal rate of returns was determined for each treatment by finding the appropriate discounting rates at which EUAW becomes zero. It was found that both EUAW and IRR become maximum in the biofloc treatment at stocking density of 1.3 Nos./ m^2.

Key words *: Rohu (Labeo rohita); Aquaculture; Biofloc technology; Economic analysis.*

Aquaculture is one of the fast-growing animal food-producing sectors at global level. In 2020, global aquaculture production reached a record 122.6 million tonnes, with a total value of USD 281.5 billion (*FAO, 2022*). In the period 1990–2020, total world aquaculture expanded by 609 per cent in annual output with an average growth rate of 6.7 percent per year (*FAO, 2022*)). India stands second in terms of aquaculture production in the world with 10.79 million metric tonne from 6.9 million hectares of freshwater area and 1.24 million hectares of brackishwater area *(NFDB, 2019)*. India's sea food export was valued at US$ 4.7 billion *(MPEDA, 2016-17)*.

The aquaculture systems in India and its neighbouring countries such as Bangladesh and Pakistan, mainly constitute Indian major carps viz. the Catla (*Catla catla*, Hamilton), the rohu (*Labeo rohita*, Hamilton), the mrigal (*Cirrhinus mrigala*, Hamilton) and sometimes the Kalbasu (*Labeo calbasu*, Hamilton). These carps contribute approximately 75 per cent to the aquaculture production in India (*FAO, 2000*). Among the Indian Major Carps, rohu is most preferred species and constitute about 35 per cent of the Indian Major Carps production (*FAO, 2000*). Nowadays, farmers prefer to stock rohu because rohu enjoys a higher consumer preference and market value (*Rahman et al., 2006*). Due to rapid environmental change, the diversification of aquaculture sector towards sustainable production has become the most fretful issue *(S akib et al., 2020)*. An additional strategy that is presently getting more attention is the removal of ammonium from the water through its assimilation into microbial proteins by the addition of carbonaceous materials to the system. If properly adjusted, added carbohydrates can potentially eliminate the problem of inorganic nitrogen accumulation (*Avnimelech, 1999*). A further important aspect of this process is the potential utilization of microbial protein as a source of feed protein for fish or shrimp (*Mahanand and Sahoo 2022*). This process is popularly known as biofloc technology. In the present study Rohu (*Labeo rohita*) has been chosen for culture due to its cheaper rate, easy accessibility as well as high market value and hardy to poorer environmental condition and its low mortality rate.

METHODOLOGY

The experimental design includes three treatments with three replications and three controls with three replications: biofloc tank fed with 20 per cent crude protein feed and extra carbohydrate and control tank fed with 30 per cent crude protein feed at three different stocking densities, viz., 1.3, 2.6 and 3.9 no per m^2 of surface area of tank. Eighteen concrete culture tanks each of capacity 0.77 m^3 were used to culture mixed sex rohu (*Labe*o rohita) of individual average weight 42 g rohu reared at three stocking densities (1.3, 2.6 and 3.9 no per m^2). The water depth was maintained at 0.89 m making the effective water volume to be 0.7 m^3. (*Mahanand et al, 2013*)

Determination of fish health indicators : More than 50 per cent of fish in each tank were sampled fortnightly, anaesthetized and length and weight measured individually. These fish were also checked for any skin or fin damage. The following growth parameters of the fish were determined.

Specific Growth Rate (SGR) = ln (Final wt/ Initial wt)/ time period

Feed Conversion Ratio (FCR) = Feed intake/ weight gain

Protein Efficiency Ratio (PER) = Wt gain of fish / protein dosed

Economic analysis of the BFT : Economic analysis of the BFT was conducted assuming the life of the project to be 10 years. Economic analysis of a system includes i) estimation of costs and returns, and ii) determination of internal rate of return. As the experiments were conducted in a very small scale, it is an obvious fact that the economics of such system will never have positive returns. Therefore, in the present study, the economic analysis of the different treatments was conducted by assuming the culture tanks to be of 1 ha capacity. The system parameters viz., amount of feed, amount of wheat flour, energy consumption etc. were further projected based on the results obtained from the model setup. The economics of the different treatments were assessed by their internal rate of returns. Equivalent Uniform Annual Worth (EUAW) was evaluated for the different treatments as the treatment units had components of different life spans. The internal rate of returns was calculated for each treatment by finding the appropriate discounting rates at which EUAW becomes zero.

Equivalent uniform annual worth (EUAW) : To adjudge an enterprise to be economic (profitable), the value of EUAW ought to be a positive (i.e. EUAW > 0).

$$EUAW = - P \times crf_{i,n} + (R-D) + S \times sfdf\ i,n$$

Where,

P = Capital cost (expenditure) towards procuring asset;

$crf_{i,n}$ (capital recovery factor) = $[\{i(1+i)n\}/\{(1+i)n - 1\}]$;

i = Minimum attractive rate of return (MARR);

n = Economic life of the asset;

R = Uniform series of end-of-period revenue income (cash in-flow) per period (say, income from sale of products) – starting at the end of the first period till the end of the life of the asset (n^{th} period);

D = Uniform series of end-of-period revenue disbursement (*cash out-flow) per period (say, expenditures towards energy consumptions, raw materials, marketing costs etc. = operating costs*) – starting at the end of the first period till the end of the life of the asset (n^{th} period); and

S = salvage value or resale value (if any) of the asset at the end of the nth period (life of the asset), here considered as zero.

A capital recovery factor (crf) is the ratio of a constant annuity to the present value of receiving that annuity for a given length of time.

Internal rate of return (IRR) : IRR (before tax) of a business venture / commercial project can be computed when all the cash flows (P, R, D, F) and life (n) of assets are given. The steps are:

i. Write the NPV or EUAW equation and substitute the numerical values for P, R, D, F, and n.

ii. Solve the equation numerically or by trial-and-error method – for “what value of i, the NPV or EUAW is zero”

Internal rates of return are commonly used to evaluate the highest rate of return that an investment or project can generate. The higher a project's internal rate of return, the more desirable it is to undertake the project. Assuming all projects require the same amount of up-front investment, the project with the highest

Table 1. Fish growth parameters in control and biofloc tanks at different stocking densities

Treatment	STD (Nos/m^2)	Average weight (kg)	Yield (kg/ha)	SGR (day^{-1})	PER	FCR
Control	1.3	0.65	7605	0.0074	0.87	3.82
	2.6	0.55	12870	0.0069	0.59	5.61
	3.9	0.50	17550	0.0067	0.48	6.88
Biofloc	1.3	0.85	10498	0.0081	1.12	2.96
	2.6	0.75	17940	0.0078	0.85	3.93
	3.9	0.65	23322	0.0074	0.84	3.95

IRR would be considered the best and undertaken first *Shang (1985).*

RESULTS AND DISCUSSION

The fish growth parameters in control and biofloc tanks are presented in Table 1. It can be seen from the table that fish yield was highest in biofloc tank with highest stocking density of 3.9 nos./m^2. However, specific growth rate (SGR) and protein efficiency ratio (PER) were highest and feed conversion rate (FCR) was lowest for biofloc treatment with lowest stocking density of 1.3 no/m^2. Thus, it can be inferred from the study that, in case of biofloc treatment at low stocking density, average fish growth would be higher compared to other treatments.

Economic analysis : Economic analysis of the BFT was conducted assuming the life of the project to be 10 years. Economic analysis of a system includes i) estimation of costs and returns, and ii) determination of internal rate of return. As the experiments were conducted in a very small scale, it is an obvious fact that the economics of such system will never have positive returns. Therefore, in the present study, the economic analysis of the different treatments was conducted by assuming the culture tanks to be of 1 ha capacity. The system parameters viz., amount of feed, amount of wheat flour, energy consumption etc. were further projected based on the results obtained from the model setup. The economics of the different treatments were assessed by their internal rate of returns. Equivalent Uniform Annual Worth (EUAW) was also evaluated for the different treatments as the treatment units had components of different life spans. The internal rate of returns was determined for each of treatments by finding the appropriate discounting rates at which EUAW becomes zero (*Singh and Thakur, 2022*).

Estimation of costs and returns

Initial investment of asset : The initial investment cost includes the total value of shed, a fish culture tank, building, equipment, and construction labor, as well as the current value of any owned assets used in the business. Salvage value on assets is the estimated value of an asset at the end of its useful life is considered as zero. The life of the project is taken as 10 years for the present study. The items considered to calculate the initial investment for the different treatments are presented in Table 2.

Table 2. Initial investment of assets with their life period

Asset	Asset life (Year)	Amount (Rs)
Compressor	25	30,000
Air stone	5	5,000
Net	5	5,000
Excavation	20	2,00,000
Construction of inlet/outlet (LS)	20	25,000
Pipelines	10	15,000
Total	2,80,000	

Recurring cost and sale price :

Recurring costs : Recurring costs include cost of energy consumption, no. of fish, fish feed, chemicals, maintenance, labour, and electrical demand charge. The kWh per kg of production was calculated by adding up the total kWh usage of the system including energy usage for compressor and other equipment converting this to kWh used per year, and then dividing by the weight of fish in kg produced. The overall energy cost of the system was found out by multiplying kWh per kg of production with kg of production.

Sale price : The current market price of harvested size of fish i.e., Rs 65 per kg was considered as sale price for economic analysis, however differential market prices for various sizes of fish as harvested in different treatments were also considered. The sale price was obtained from fish market. The recurring cost and selling price for each of the different treatments per year per ha area are presented in Table 3–4. The calculations were based on the results obtained from the model experiments. In control condition it was found that the net return over variable cost was highest at STD 1.3 nos/m^2. Similarly, in Biofloc treatment, net return over

Table 3. Variable cost (per ha) and total revenue (per ha) of control treatments at different stocking density

Control Treatment at different stocking density (STD)					
(STD - 1.3 nos/m2)		STD – 2.6 nos/m2		STD – 3.9 nos/m2	
Particulars of variable cost	Amount (Rs/year/ha)	Particulars of variable cost	Amount (Rs/year/ha)	Particulars of variable cost	Amount (Rs/year/ha)
Energy @ 2.5 Rs/kWh	50000.0	Energy (Rs/kWh)	75000.0	Energy (Rs/kWh)	100000.0
Fish 13000 Nos.@ Rs. 5/Nos.	65000.0	Fish 26000 Nos.@ Rs. 5/Nos.	130000.0	Fish 39000 Nos.@ Rs. 5/Nos.	195000.0
Chemical @ Rs.10000/ha	10000.0	Chemical @ Rs.15000/ha	15000.0	Chemical @ Rs 30000/ha	30000.0
Maintenance @ Rs.10000/ha	10000.0	Maintenance @ Rs 15000/ha	15000.0	Maintenance @ Rs 30000/ha	30000.0
Fish Feed @ Rs 40/kg	280000.0	Fish Feed @ Rs 40/kg	500000.0	Fish Feed @ Rs 40/kg	660000.0
Water Exchange Cost	7500.0	Water Exchange Cost	20000.0	Water Exchange Cost	45000.0
Miscellaneous including Harvesting, Transportation, Marketing expenses and Watch and Ward etc.	7500.0	Miscellaneous including harvesting, Ttransportation, marketing expenses and watch and ward etc.	25000.0	Miscellaneous including harvesting, transportation, marketing expenses and watch and ward etc.	30000.0
Total	430000.0		780000.0		1090000.0
Particulars of total revenue (PXQ) and net return amount (Rs/year/ha)					
Sale Price – 7605 kg/ha fish with sale price @ 65 per kg	494325.0	Sale Price – 12870 kg fish @ 65 per kg	836550.0	Sale Price – 17550 kg fish @ 65 per kg	1140750.0
Net return over variable cost (Rs./ha)	64325.0		56550.0\		50750.0

Table 4. Variable cost (per ha) and total revenue (per ha) of Biofloc treatment at different stocking density

Biofloc treatment at different stocking density					
STD - 1.3 nos/m2		STD – 2.6 nos/m^2		STD – 3.9 nos/m2	
Particulars of recurring expenditures	Amount (Rs/year/ha)	Particulars of recurring expenditures	Amount (Rs/year/ha)	Particulars of recurring expenditures	Amount (Rs/year/ha)
Energy (Rs/kWh)	60000.0	Energy (Rs/kWh)	100000.0	Energy (Rs/kWh)	125000.0
Fish 13000 Nos.@ Rs 5/Nos.	65000.0	Fish 26000 Nos.@ Rs. 5/Nos.	130000.0	Fish 39000 Nos.@ Rs. 5/Nos.	195000.0
Chemical @ Rs 5000/ha	5000.0	Chemical @ Rs 8000/ha	8000.0	Chemical @ Rs13000/ha	13000.0
Maintenance @ Rs 5000/ha	5000.0	Maintenance @ Rs 8000/ha	8000.0	Maintenance @ Rs 13000/ha	13000.0
Fish Feed @ Rs 30 per kg	280000.0	Fish Feed @ Rs 30 per kg	500000.0	Fish Feed @ Rs 30 per kg	650000.0
Wheat Flour @ Rs 15 per kg	175000.0	Wheat Flour @ Rs 15 per kg	340000.0	Wheat Flour @ Rs 15 per kg	440000.0
Water exchange cost	5000.0	Water exchange Cost	7500.0	Water exchange cost	10000.0
Miscellaneous including harvesting, transportation, marketing expenses and watch and ward etc.	5000.0	Miscellaneous including harvesting, transportation, marketing expenses and watch and ward etc.	7500.0	Miscellaneous including harvesting, transportation, marketing expenses and watch and ward etc.	10000.0
Total	600000.0		1101000.0		1456000.0
Particulars of Total Revenue (PXQ) and net return amount (Rs/year/ha)					
Sale Price – 10498 kg fish @ 65 per kg	682370.0	Sale Price – 17940 kg fish @ 65 per kg	1166100.0	Sale Price – 23320 kg fish @ 65 per kg	1515930.0

variable cost was highest at STD 1.3 nos/m^2.

Variation of EUAW and IRR in control and biofloc treatments

Equivalent uniform annual worth (EUAW) : To adjudge that biofloc enterprise is economically viable (profitable), the value of EUAW ought to be a positive value (i.e. EUAW > 0). Assuming the discount rate to be 10 per cent, the values of EUAW for the different treatments in the present study were computed using Eq. (1) and presented as follows:

It can be seen from Table 5 that EUAW becomes maximum in the biofloc treatment conducted at stocking density of 1.3 Nos./ m^2. It can also be observed that EUAW decreases with increasing stocking density irrespective of treatments. Further, at a particular stocking density, EUAW is more in case of biofloc when compared with the control treatment.

Internal rate of return (IRR) : Internal rates of return are commonly used to evaluate the desirability of investments or projects. The higher IRR, the more desirable it is to undertake the project. Assuming all projects require the same amount of up-front investment, the project with the highest IRR would be considered the best and undertaken first. IRR of the different treatments considered in the present study was computed numerically by setting EUAW = 0. The values of IRR for different treatments are presented in Table 6.

It can be observed from the above table that IRR becomes maximum (29.4 %) in the biofloc treatment conducted at stocking density of 1.3 Nos./m^2. It can also be observed that IRR gradually decrease with increase stocking density. Further, at a particular stocking density, IRR is more in case of biofloc when compared with the control treatment.

Table 5. Variation of EUAW for control and biofloc treatments at discount rate, i = 10%

Treatment	STD (no/m^2)	EUAW at i = 10%
Control	1.3	36329
	2.6	28554
	3.9	22754
Biofloc	1.3	54374
	2.6	37104
	3.9	31934

Table 6. Variation of IRR for control and biofloc treatments

Treatment	Stocking density (nos/m^2)	Internal rate of return (%)
Control	1.3	23.00
	2.6	20.20
	3.9	18.00
Biofloc	1.3	29.40
	2.6	23.25
	3.9	21.40

CONCLUSION

As the experiments were conducted in a very small scale, the economic analysis of the different treatments was conducted by assuming the culture tanks to be of 1 ha-m capacity. The economics of the different treatments were assessed by their internal rate of returns. Equivalent Uniform Annual Worth (EUAW) was evaluated for the different treatments as the treatment units had components of different life spans. The internal rate of returns was determined for each treatment by finding the appropriate discounting rates at which EUAW becomes zero. It was found that both EUAW and IRR become maximum in the biofloc treatment at stocking density of 1.3 Nos./ m^2. The growth rate, average weight, specific growth rate (SGR) and protein efficiency ratio (PER) of rohu were found to be maximum in the biofloc treatment conducted at a low stocking density of 1.3 Nos./m^2. The economic analysis showed that IRR becomes maximum (29.40) in the biofloc treatment at stocking density of 1.3 Nos./ m^2. The 29.40 IRR indicates considerably better for investment opportunities in the project.

CONFLICTS OF INTEREST

The authors have no conflicts of interest.

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