Original Research Article

Economic Viability and Operational Efficiency: A Comparative Study of Biofloc and Traditional Aquaculture

Abstract

Aquaculture has emerged as a vital component of the Indian agrarian economy, playing a significant role in enhancing food security, generating income, and promoting rural livelihoods. As one of the largest producers of inland fish in the world, India has leveraged its vast water resources to develop a robust aquaculture sector, contributing to the diversification of agriculture and the overall economic development of the country. In this context, a comprehensive analysis of biofloc and traditional aquaculture methods was carried out to kow the differences in economic and operational aspects between them. The results reveal that, biofloc aquaculture requires a substantially higher initial investment compared to traditional methods, as indicated by a significant t-test result. However, feed costs showed no significant difference. Labour wages are notably higher in biofloc, indicating socioeconomic implications. Financial analysis highlights biofloc's financial viability, with positive contribution margins, operating profits, and favourable break-even metrics. Traditional aquaculture, despite lower initial investments, suffers from negative operating profits and a margin of safety deficit. Stakeholder perceptions indicate biofloc's higher productivity, profitability, and operational ease, but acknowledge challenges such as higher initial investments and complexity. Traditional aquaculture, while cost-effective initially, lacks profitability and ease of operation. The findings suggest prioritizing biofloc technology, emphasizing the need for institutional support and subsidies to make it economically viable and accessible to the aqua culturist community.

1. Introduction

Historical Roots and Evolution of Aquaculture in India: Aquaculture, the art and science of cultivating aquatic organisms, traces its roots to ancient civilizations like the Egyptians, Chinese, and Romans, who constructed ponds and aqueducts for fish farming. In India, texts like the Arthashastra and Manusmriti document fish rearing practices dating back thousands of years. The Mauryan and Gupta Empires laid significant foundations for Indian aquaculture, leveraging the Ganges River's fertile waters (Rutaisire*et al*., 2017).Modern Developments and Government Initiatives: The Blue Revolution in the late 1980s marked a turning point for India's freshwater aquaculture, leading to technological advancements and increased fish production (singh*et al*). By the 1990s, India produced over 2 million metric tons of freshwater fish annually. The establishment of the National Fisheries Development Board in 2006 and schemes like the Integrated Fisheries Development Scheme and Rashtriya Krishi Vikas Yojana (RKVY) further bolstered the sector, promoting sustainable practices and improving infrastructure (Hassan*et al*.,2017).States like Andhra Pradesh, West Bengal, Odisha, and Tamil Nadu have significantly contributed to India's aquaculture growth. Andhra Pradesh, known as the "Aqua Hub of India," adopted innovative techniques and policies, increasing its share in India's fish production from 17.7% in 2011-12 to 40% in 2020-21 (Nisar *et al*., 2022). Similarly, Karnataka has implemented state-of-the-art technologies, resulting in consistent growth in Gross Value Output (GVO) (Mugwanya*et al*., 2021).

Traditional aquaculture is the aquaculture operated tthrough ponds are that created through site selection, excavation, and pond design, focusing on water depth, soil type, and topography. Common species include Catla (Catla catla) and Rohu (Labeorohita), valued for their adaptability, growth rate, and economic significance (Azim *et al.*, 2002). While Biofloc systems use geomembrane-lined tanks and aeration to promote beneficial microbial communities, enhancing water quality and fish health. This method conserves resources and creates a controlled environment for fish culture Ray et al., 2020). In Bengaluru, species like Tilapia and Murrel (snakehead fish) are preferred for their adaptability and productivity in biofloc systems (Khanjani*et al*., 2020).Biofloc method is an advanced method than the traditional method, hence these two methods are being compared in this study.

Karnataka has embraced biofloc technology, which promotes intensive fish farming within a closed-loop system, conserving water and land resources and improving waste management (Body *et al*., 2000). The state's proactive approach includes training programs, workshops, and financial assistance schemes to facilitate bioflocadoption. This research aims to evaluate the economic aspects of traditional and biofloc-based fish production systems in India, comparing costs, yields, and profitability, and exploring their environmental and social implications. By analysing these factors, this study seeks to providevaluable insights for policymakers, fish farmers, and stakeholders in India's aquaculture sector.

1.1.Data description

For this study, a sample of 30 traditional pond farmers and 30 biofloc system practitioners in Bengaluru was selected. The sampling process involved purposive sampling, ensuring a representative cross-section of aqua culturists. A structured questionnaire was designed to gather primary data on various aspects, including pond construction practices, operational challenges, and economic considerations. The questionnaire was administered through interviews with the participating farmers, allowing for in-depth insights into their experiences and perspectives on traditional and biofloc aquaculture.

2. **Data and methodology:**

2.1. Data

This study is mainly based on the field surveys conducted with 60 aqua culturists located in Bengaluru Rural district of Karnataka. Of the 60 farmers 30 were traditional pond farmers and rest 30 were biofloc system practitioners. Simple random sampling was carried out to get the better estimates.A structured and pre tested questionnaire was designed to gather primary data on various aspects of aquaculture, including pond construction practices, operational challenges, and economic considerations. Apart from the quantitative aspects of aquaculture, qualitative information like farmers perception about the aquaculture practices were also collected. And questionnaire was administered through interviews with the respondents, allowing for in-depth insights into their experiences and perspectives on traditional and biofloc aquaculture.

2.2. Analytical tools and techniques

Statistical analysis will be performed on the collected data to draw meaningful conclusions. A comparative analysis will highlight distinctions between traditional and biofloc systems in construction practices, operational dynamics, and economic outcomes.

2.2.1. Independent t-test: An independent t-test determines whether there is a significant difference between the means of two groups.

- **Equal Variance:** The t-statistic is calculated as:

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{S_1^2}{N_1} + \frac{S_2^2}{N_2}}}$$

  With degrees of freedom (df) = (n_1+n_2-2).

- **Unequal Variance:** Using Welch's degrees of freedom and standard error:

$$t = \frac{(\bar{X}_1 - \bar{X}_2) - (\mu_1 - \mu_2)}{\sqrt{(s_1^2/n_1 + s_1^2/n_2)}}$$

  With degrees of freedom approximated by the Welch-Satterthwaite equation (Gopan *et al*., 2022).

2.2.2. Cost Structure Analysis: This analysis assesses the performance and risk associated with traditional and biofloc aquaculture (Puerto *et al*., 2021).

- **Yield Calculation:** Range of crop yield in kilograms.
- **Selling Cost per Unit:** Minimum, average, and maximum costs.
- **Sales Revenue Calculation:** Yield multiplied by selling cost per unit.
- **Variable Cost per Unit:** Costs that vary with the number of units produced.
- **Total Variable Cost:** Variable cost per unit multiplied by yield.
- **Contribution Margin:** Sales revenue minus total variable cost.
- **Fixed Cost Identification:** Data on fixed costs for the specified period.
- **Operating Profit:** Contribution margin minus fixed costs.
- **Operating Leverage:** Contribution margin divided by operating profit.
- **Break-Even Analysis:** Fixed costs divided by contribution margin.
- **Margin of Safety:** Percentage difference between actual sales and break-even point.
- **Percentage of Sales for Break-Even Point:** Break-even sales revenue divided by total sales revenue.

2.2.3. Percentage Analysis: Based on feedback using a Likert scale for both traditional and biofloc systems.

- **Organize Data:** Table with rows for respondents and columns for Likert scale items.
- **Count Responses:** For each Likert scale item, count respondents for each response option.

- **Calculate Percentages:** For each option, calculate the percentage of respondents selecting it.
- **Present Results:** Use tables or charts to show the distribution of responses for each Likert scale item.

3. Results and discussion

3.1. Comparison between traditional aquaculture and biofloc aquaculture:

The economic analysis of biofloc and traditional pond-based fish production reveals key insights into their respective economic performances. Using an independent t-test, the study evaluated initial investment, feed cost, and labour cost, identifying significant differences between the two technologies. Key indicators, such as yield per kilogram, selling costs, and sales revenue, were analysed to understand productivity and market potential. The financial sustainability and profitability of each approach were assessed through variables like contribution margins and operating profits. A break-even analysis, including break-even sales revenue, margin of safety, and percentage of sales for the break-even point, provided a comprehensive view of resilience and risk exposure (Sathiadhas*et al*., 2009).

A two-sample t-test was conducted to compare the initial investments of Traditional and Biofloc systems, assuming unequal variances and the results are presented in Table 1. The Traditional system had a mean initial investment of Rs. 4, 05,586, significantly lower than the Bioflocsystem's mean of Rs. 9, 77,586. The calculated t-statistic was -26.94 with 46 degrees of freedom, and the one-tailed p-value was 0.000, well below the 0.01 significance level. The two-tailed p-value was similarly low at 0.000, providing strong evidence to reject the null hypothesis.Considering the t-critical values for both one-tailed (1.68) and two-tailed (2.01) tests, the calculated t-statistic far exceeds these critical values. This indicates a significant difference in mean initial investments between the two systems. In conclusion, the Traditional system requires a substantially lower initial investment compared to the Biofloc system, as evidenced by the extremely low p-values and significant t-statistic.

Table 1: Difference of mean test between traditional and biofloc technology on initial investment (Assuming unequal variance)

	Traditional	**Biofloc**
Mean	405586.2	977586.2
Variance	3.15E+09	9.57E+09
Observations	29	29
Hypothesized mean		
Difference	0	
Df	46	
T stat	-26.93	
P(T<=t) one tail	0.0000	
T critical one tail	1.67	
P(T<=t) two tail	0.0000	
T critical two-tail	2.012	

Source: Authors' calculations based on primary data.

A two-sample t-test, assuming unequal variances, compared feed costs between Traditional and Biofloc systems is presented in Table 2. The mean feed cost was Rs. 2, 05,606.44 for Traditional and Rs. 2, 51,825.53 for Biofloc. The t-statistic was -1.02 with 30 degrees of freedom. The p-values were 0.16 (one-tailed) and 0.32 (two-tailed), both exceeding the 0.05

significance level. These results indicate insufficient evidence to reject the null hypothesis of no difference in mean feed costs. With the t-statistic not surpassing the critical values of 1.70 (one-tailed) and 2.04 (two-tailed), the observed variation may be due to chance.

Table 2: Difference of mean test between traditional and biofloc technology onfeed cost(Assuming unequal variance)

	Traditional	**Biofloc**
Mean	205606.44	251825.53
Variance	1665893879	57839546941
Observation	29	29
Hypothesized Mean	0	
Difference	0	
Df	30	
T stat	1.0203	
P(T<=t) one-tail	0.1579	
t Critical one-tail	1.6973	
P(T<=t) two-tail	0.3157	
t Critical two-tail	2.0423	

Authors' calculations based on primary data.

The independent t-test on labour wages between biofloc and traditional pond-based systems shows a significant difference. Mean wages for biofloc workers were Rs. 12,233.33, notably higher than Rs. 7,100 in the traditional system. The t-statistic of 17.96 exceeds the critical value, and the p-values are near zero, indicating a high confidence in rejecting the null hypothesis. This result highlights a substantial difference in labour wages between the two systems. Workers in biofloc aquaculture earn significantly more, potentially due to factors like skill requirements or working conditions. This information is valuable for stakeholders in assessing workforce compensation and economic sustainability.

Table 3: Difference of mean test between traditional and biofloc technology on labour wages(Assuming unequal variance)

	Biofloc	**Traditional**
Mean	12233	7100
Variance	1857471	593203.4
Observations	30	30
Hypothesized Mean		
Difference	0	
Df	46	
T stat	17.9608	
P(T<=t) one-tail	0.0000	
t Critical one-tail	1.6786	
P(T<=t) two-tail	0.0000	
t Critical two-tail	2.012	

Authors' calculations based on primary data.

3.2. Financial analysis of traditional and biofloc aquaculture systems:

Financial feasibility of the both aquaculture farms was carried by computing the gross returns, operational profit, breakeven point, margin of safety, etc. In the biofloc system, yields range from 4,158 to 12,384 kilograms, with selling costs per unit between Rs. 32.67 and Rs.

261, leading to sales revenues from Rs. 1, 35,841to Rs. 32, 32,224 (Table 4). Variable costs per unit range from Rs. 6 to Rs. 63, resulting in total variable costs of Rs. 24,948 to Rs. 7, 80,192. Contribution margins vary significantly, from Rs. 1, 10,893to Rs. 24, 52,032. Fixed costs amortize between Rs. 80,000 and Rs. 90,000, yielding operating profits between Rs. 30,893and Rs. 23, 62,032. The break-even sales revenue ranges from Rs. 97,997 to Rs. 1, 18,636, indicating the sales needed to cover all costs. The margin ofsafety ranges from 27.86% to 96.33%, reflecting a strong financial cushion. The percentage of sales required to break even ranges from 3.67% to 72.14%, showing operational efficiency. Overall, the biofloc system demonstrates robust financial stability and resilience.

Table 4: Financial analysis of Biofloc aquaculture production

	Minimum	Average	Maximum
Yield in Kg	4158	6522	12384
Selling cost per unit	32.67	141	261
Sales revenue	135841	919570	3232224
Variable cost per unit	6	35	63
Total variable cost	24948	228262.06	780192
Contribution	11892	691307	2452032
Fixed cost	80000	98333.3	90000
Operating Profit	30893	592974	2362032
Operating leverage	3.58	1.16	1.03
Break-even amount of sales revenue	97997	130801	118636
Margin of safety	27.86%	85.78%	96.33%
Percentage of sales for break-even point	72.14%	14.22%	3.67%

Authors' calculations based on primary data.

Traditional aquaculture shows lower yields and higher costs compared to biofloc aquaculture (Table 5. Selling costs per unit range from Rs.32.63 to Rs.67.45, while variable costs per unit are between Rs.31 and Rs.61. This results in total variable costs from Rs.55, 242 to Rs.2, 63,620 and contribution margins of Rs.2,895 to Rs.27,932. Fixed costs amortize from Rs.38,000 to Rs.43,000, leading to negative operating profits ranging from -Rs.35,104 to -Rs.15,067, and a negative operating leverage, indicating less sensitivity to sales changes. The break-even sales revenue ranges from Rs.4, 48,825 to Rs.7, 62,923, highlighting the need for significant sales increases to cover costs. The negative margin of safety, ranging from -53.94% to -1212.27%, emphasizes financial vulnerability. In contrast, biofloc aquaculture offers higher yields, sales revenue, and a lower break-even point, presenting a more financially resilient model.

Table 5: Financial analysisof Traditional aquaculture production

	Minimum	Average	Maximum
Yield in Kg	1782	3087	4323
Selling cost per unit	32.63	56.34	67.45
Sales revenue	58137	173934	291552
Variable cost per unit	31	53	61

Total variable cost	55242	162123	263620
Contribution	2895	11810	27932
Fixed cost	38000	41007	43000
Operating Profit	-35104	-29195	-15067
Operating leverage	-0.08249	-0.40454	-1.8538
Break-even amount of sales revenue	762923	603894	448825
Margin of safety	-1212.27%	-247.20%	-53.94%
Percentage of sales for breakeven point	1312.27%	347.20%	153.94%

Authors' calculations based on primary data.

3.3. Percentage analysis:

A detailed percentage analysis using a Likert scale gauged perceptions of aqua culturists regarding nature of tasks, water quality management, operating costs, simplicity of operation, and initial investment. Here the perceptions of farmers are presented as the percentage of farmers who expresses similar feeling. These qualitative insights complemented the quantitative economic metrics, offering a holistic understanding of the economic dynamics between biofloc and traditional pond-based fish production methods**.**

In traditional aquaculture, task difficulty ranges from moderate to up to very difficult as perceived by the aqua culturists (Table 6). While biofloc aqua culturists feelsthat the tasks are easy to moderate, with no initial difficulty or very difficult tasks. This indicates biofloc has a more manageable difficulty progression.

Table 6: Perception of aqua culturistsabout the nature of task.

	Traditional	Biofloc
Very Easy	0	0
Easy	0	22.22
Moderate	26.82	77.77
Difficult	16.26	0
Very Difficult	56.91	0

Authors' calculations based on primary data.

In managing water quality, the Traditional method shows ease ratings from 5.43 to 32.61, indicating increasing difficulty (Table 7). In contrast, the Biofloc method ranges from 16.09 to 36.78, reflecting generally moderate and consistent difficulty. This suggests that Biofloc offers a more stable and manageable approach to water quality.

Table 7: Table indicating opinion of aqua culturists on Water quality management

	Traditional	Biofloc
Very Easy	5.43	16.66
Easy	8.69	16.09
Moderate	16.30	24.13
Difficult	17.39	36.78
Very Difficult	32.60	17.24

Authors' calculations based on primary data.

In the aqua culturists' perception, operating costs for the traditional method is quite less as compared with the biofloc method (Table 8).As Biofloc method has lower initial costs but higher costs at advanced stages, suggesting varied economic feasibility between the two approaches.

Table 8: Table indicating opinion of aqua culturists on Operating Costs

	Traditional	Biofloc
Very Low	14.93	0
Low	20.89	0
Moderate	40.30	25.21
High	23.88	36.97
Very High	0	37.82

Authors' calculations based on primary data.

Aqua culturists' perception on initial investment in aquaculture shows that traditional method involves moderate to less investment as compared to the biofloc method (Table 9). This indicates that while the Traditional method is perceived as having a lower initial investment, Biofloc, despite a lower start, may demand a higher investment over time. This insight helps aqua culturists choose between methods based on their financial planning and investment capacity.

Table 9: Table indicating opinion of aqua culturists on Initial Investment

	Traditional	Biofloc
Very Low	15.52	0
Low	48.27	0
Moderate	36.21	25.64
High	0	44.44
Very High	0	29.91

Authors' calculations based on primary data.

4. Conclusion

The analysis of biofloc versus traditional aquaculture highlights several key differences. Biofloc requires a significantly higher initial investment, as revealed by the t-test, though feed costs between the two methods are similar. Labour wages are higher in biofloc, reflecting potential socioeconomic impacts. Financially, biofloc shows positive contribution margins, operating profits, and favourable break-even metrics, indicating strong viability. In contrast, traditional aquaculture, while lower in initial investment, suffers from negative operating profits and a large margin of safety deficit. The percentage analysis across various factors, including discharge management, energy consumption, and water quality, suggests biofloc offers better productivity, profitability, and perceived ease of operation, despite its higher initial costs and complexity. Traditional aquaculture is more cost-effective initially but struggles with profitability and operational ease. To enhance biofloc's adoption, promoting it through institutional support and subsidies for the initial investment is crucial, aiming to make it more accessible and economically viable for the aqua culturist community.

5. References:

Azim, M. E., Verdegem, M. C. J., Khatoon, H., Wahab, M. A., Van Dam, A. A., & Beveridge, M. C. M. (2002). A comparison of fertilization, feeding and three periphyton substrates for increasing fish production in freshwater pond aquaculture in Bangladesh. Aquaculture, 212(1-4), 227-243.

Boyd, C. E., and Gross, A. (2000). Water use and conservation for inland aquaculture ponds. Fisheries management and Ecology, 7(1□2), 55-63. 791738.

Genç, E., Kaya, D., and Genç, M. A. (2019, July). Biofloc as an economical and applicable production technology for the sustainability of aquaculture production. In Book of Proceedings (p. 49).

Gopan, S., S. K. P., Das, A., Kaippilly, D., B, S, G., and Rani, B., (2022). Economic evaluation of biofloc fish culture during the Covid-19pandemic in Kerala, west coast of India. J. Indian Fish Assoc., 45(01)

Hassan, M. A., Mishal, P., Karnatak, G., & Sharma, A. P. (2017). Towards the blue revolution in India: prospects for inland open waters. World Aquacult, 48(1), 25-28.

Jayasankar, P. (2018). Present status of freshwater aquaculture in India-A review. Indian Journal of Fisheries, 65(4), 157-165.

Katiha, P. K., Jena, J. K., Pillai, N. G. K., Chakraborty, C., & Dey, M. M. (2005). Inland aquaculture in India: past trend, present status and future prospects. Aquaculture Economics & Management, 9(1-2), 237-264.

Khanjani, M. H., &Sharifinia, M. (2020). Biofloc technology as a promising tool to improve aquaculture production. Reviews in aquaculture, 12(3), 1836-1850.

Mugwanya, M., Dawood, M. A., Kimera, F., &Sewilam, H. (2021). Biofloc systems for sustainable production of economically important aquatic species: A review. Sustainability, 13(13), 7255.

Nisar, U., Peng, D., Mu, Y., & Sun, Y. (2022). A solution for sustainable utilization of aquaculture waste: a comprehensive review of biofloc technology and aquamimicry. Frontiers in Nutrition, 8, 791738.

Ray, A., & Mohanty, B. (2020). Biofloc Technology: An Overview and Its Application. Biotica Res. Today, 2(10), 1026-1028.

Rutaisire, J., Nandi, S., &Sundaray, J. K. (2017). A review of Uganda and Indias freshwater aquaculture: Key practices and experience from each country. Journal of Ecology and the Natural Environment, 9(2), 15-29.

Sathiadhas, R., Najmudeen, T. M., & Prathap, K. S. (2009). Break-even Analysis and Profitability of Aquaculture Practices in India. Asian Fisheries Science, 22(2), 667-680.

Sicuro, B. (2021). World aquaculture diversity: origins and perspectives. Reviews in Aquaculture, 13(3), 1619-1634.

Singh, C., Rani, P., & Kumar, K. IMPACT OF BLUE REVOLUTION IN INDIA AN ANALYTICAL STUDY.

Suárez-Puerto, B., Delgadillo-Díaz, M., Sánchez-Solís, M. J., &Gullian-Klanian, M. (2021). Analysis of the cost-effectiveness and growth of Nile tilapia (Oreochromis niloticus) in biofloc and green water technologies during two seasons. Aquaculture, 538, 736534.