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Comparative Evaluation of Growth Performance, Mortality Rate, Survival Rate, and Feed Conversion Ratio (FCR) of *Pangasius pangasius* in Biofloc Tank and Cage Culture Systems

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Abstract: The growing demand for aquatic protein in India calls for efficient and sustainable aquaculture systems. Pangasius pangasius, a native freshwater catfish, shows great potential due to its fast growth and adaptability. This study compared two systems: T1 (Biofloc in 10,000 L HDPE tanks) and T2 (Cage culture in nylon cages in a pond), each stocked with 150 fingerlings (initial avg. 6 g, 4 cm). Growth performance, SGR, FCR, survival, and mortality were recorded biweekly. Biofloc consistently outperformed cage culture, showing higher final weights (up to 1130 g), better SGR (up to 3.0%/day), lower FCR (1.2), and higher survival (90%). Cage culture showed lower growth (up to 800 g), higher FCR (1.6), and 85% survival. Biofloc proved more effective across seasons, offering better water quality, microbial protein support, and system stability. The study suggests Biofloc is a more sustainable and economically viable option for P. pangasius farming, especially in resource-limited areas. Further economic and environmental studies are recommended.
Keywords: Aquaculture Systems, Biofloc, Cage Culture, Feed Conversion Ratio, Growth Performance, Mortality Rate, Pangasius pangasius, Survival Rate.

I. INTRODUCTION

Aquaculture has emerged as one of the most vital components of the global food production system, contributing significantly to food security, nutrition, and livelihoods (FAO, 2022). As capture fisheries face stagnation due to overfishing and environmental degradation, aquaculture presents a sustainable solution to meet the increasing demand for aquatic protein (Bostock et al., 2010). The intensification of aquaculture practices, particularly in developing countries like India, has led to the adoption of various advanced culture systems aimed at improving productivity, efficiency, and environmental sustainability (De Silva & Soto, 2009). Aquaculture has evolved significantly over the last few decades and now stands as one of the most dynamic and rapidly growing sectors within global food production (FAO, 2022). With increasing pressure on wild fish stocks and a rising global population, aquaculture provides a sustainable and reliable source of high-quality protein.

According to the Food and Agriculture Organization (FAO, 2022), aquaculture now contributes to more than 50% of the world's fish consumption, and this proportion is expected to grow in the coming decades. Freshwater aquaculture plays a particularly vital role in developing countries, where it supports rural livelihoods, nutritional security, and economic development (Ahmed & Garnett, 2011). Traditional systems such as pond culture and cage culture have long been utilized in countries like India and Bangladesh. However, these systems are increasingly being scrutinized for their environmental impact, disease outbreaks, inefficient feed utilization, and dependency on natural water quality (Tucker & Hargreaves, 2008).

In response to these limitations, new aquaculture systems such as Biofloc Technology (BFT) have been developed. These systems promise not only to enhance productivity and profitability but also to address sustainability concerns associated with traditional practices (Avnimelech, 2015). Among the many species cultivated in freshwater aquaculture, *Pangasius pangasius*, commonly known as the Indian catfish, holds considerable potential due to its high growth rate, adaptability to varied environmental conditions, resistance to diseases, and growing consumer acceptance (Jena et al., 2005). Native to the Indian subcontinent, *P. pangasius* is traditionally cultured in ponds and open water bodies. However, with increasing demand for high-density, resource-efficient aquaculture systems, there is a pressing need to evaluate its performance under modern intensive systems.

Unlike its exotic cousin *Pangasianodon hypophthalmus* (widely farmed in Vietnam and Thailand), *P. pangasius* is more tolerant to local environmental conditions, diseases, and water temperature fluctuations (Das et al., 2021). Additionally, it has a strong cultural and culinary presence in India and Bangladesh, which makes its domestication and culture particularly promising for sustainable aquaculture expansion. Despite these advantages, the species has not received as much research attention as *P. hypophthalmus*, particularly in the context of modern culture systems like biofloc technology. A thorough scientific understanding of how *P. pangasius* performs in different culture environments is essential to maximize its production and economic viability.

Two such systems Cage Culture and Biofloc Technology (BFT) offer contrasting approaches to fish farming. Cage culture involves rearing fish in enclosures suspended in natural water bodies such as rivers, reservoirs, and lakes. It provides the advantage of utilizing existing water resources with minimal infrastructure (Beveridge, 2004). However, this method is often limited by fluctuating water quality, disease transmission from the external environment, and poor waste management. In contrast, biofloc technology is a relatively newer and innovative aquaculture system that recycles nitrogenous waste through the stimulation of microbial communities. By maintaining a high carbon-to-nitrogen (C:N) ratio, heterotrophic bacteria convert harmful ammonia into microbial biomass (bioflocs), which serve as a supplemental protein-rich feed for the fish (Avnimelech, 2015). Biofloc systems offer improved feed efficiency, better water quality, and reduced environmental discharge, making them a promising alternative to conventional methods (Crab et al., 2012).

In evaluating any aquaculture system, certain performance indicators are crucial. Growth performance, measured through parameters like weight gain and specific growth rate (SGR), reflects the efficiency of the system in converting inputs into biomass. Mortality rate and survival rate are key indicators of fish health and environmental suitability. Equally important is the Feed Conversion Ratio (FCR), which indicates how efficiently feed is utilized to produce fish biomass a critical factor influencing the economic viability of aquaculture operations (Tacon & Metian, 2008). While considerable research has been conducted on exotic species like *Pangasianodon hypophthalmus* in both cage and biofloc systems, studies focusing on the native *Pangasius pangasius* remain limited (Das et al., 2021). This knowledge gap hinders the development of effective and sustainable farming protocols for this species, which has high potential in India and neighboring countries.

The present study aims to address this gap by conducting a comparative evaluation of the growth performance, mortality rate, survival rate, and feed conversion ratio of *Pangasius pangasius* cultured in Biofloc and Cage Culture systems. The objective is to identify the more suitable culture system for this species in terms of biological efficiency and sustainability. This research is expected to provide valuable insights for fish farmers, researchers, and policymakers involved in the development and promotion of sustainable aquaculture practices.

A. Study Location and Duration

The experimental study was conducted at the Samradhi fish farm, Bhopal, M.P., over a period of 1 year from October 2023 to September 2024. Two different culture environments Biofloc system and Cage Culture system were set up to conduct parallel trials for comparative analysis.

II. METHODOLOGY

A. Experimental Design and Setup of Biofloc tank and cage culture

A completely randomized design (CRD) was used with two treatment groups:

T1: *Pangasius pangasius* cultured in a Biofloc system. In the Biofloc system, circular or rectangular tanks made of high-density polyethylene (HDPE) or fiber-reinforced plastic (FRP) are commonly used due to their durability, chemical resistance, and ease of maintenance. For this study, circular HDPE tanks with a capacity of 10,000 liters were selected to facilitate better mixing and ease of aeration (Avnimelech, 2015 and Hargreaves, 2013). The tanks had smooth surfaces to prevent microbial buildup in unwanted areas and were opaque to reduce algal growth caused by light penetration. The tanks were installed indoors or under shade to maintain optimal water temperature and reduce stress on cultured fish. The tank dimensions ensured adequate volume to maintain biofloc concentration and fish stocking density, while also allowing easy sampling and cleaning (Crab et al., 2012).

Aeration is essential in biofloc systems to maintain dissolved oxygen levels above 5 mg/L and keep biofloc particles suspended, which supports microbial activity and fish health. In this study, continuous aeration was provided using air blowers connected to evenly placed air stones at the tank bottom. Fine bubbles ensured efficient oxygen transfer and water circulation, preventing floc settling. Aeration rates were adjusted based on fish biomass and water quality (Emerenciano et al., 2013). Water exchange was minimal, done only to offset evaporation, as the system naturally recycles nitrogenous waste.

T2: *Pangasius pangasius* cultured in a Cage Culture system. Cage culture employs floating cages constructed using nylon or polyethylene netting supported by a rigid frame made from galvanized iron (GI) or PVC pipes. The cages used in this study measured 6m (L) x 4m (W) x 4m (H) were installed in a pond water body with appropriate water depth and current (FAO, 2015). The cages were made of nylon netting supported by a galvanized iron frame and anchored securely. Natural water exchange and environmental conditions prevailed in this system and were suspended in a freshwater reservoir with adequate depth to ensure good water exchange. The netting mesh size was selected to retain fingerlings but allow water flow and waste removal. Frames were corrosion-resistant and anchored firmly using ropes and weights to prevent displacement due to water currents or wind. The cage design also allowed for easy access for feeding and fish harvesting. In cage culture systems, water circulation depends primarily on natural water currents in the reservoir or water body. The open design of the cages allows free water flow, which aids in oxygen replenishment and removal of metabolic wastes from the fish. No mechanical aeration is typically provided unless water quality deteriorates. However, cage sites are selected based on adequate water flow to prevent stagnation and ensure a healthy environment (Beveridge, 2004).

B. Stocking of Fingerlings

Healthy *Pangasius pangasius* fingerlings with an average initial weight of 6 g and an average length of 4 cm were procured from a certified hatchery. Prior to stocking, the fingerlings were acclimatized for seven days under controlled conditions and treated prophylactically with potassium permanganate ($KMnO_4$) at a concentration of 2 ppm to eliminate ectoparasites (Boyd and Tucker, 1998). In the cage culture system, cages measuring 6m (L) x 4m (W) x 4m (H) were used, while in the biofloc system, circular HDPE tanks with a capacity of 10,000 liters were utilized. A uniform stocking density of 150 fingerlings was maintained in both the cage and biofloc systems, adjusted proportionally to the water volume to ensure standardization across treatments.

C. Growth Performance and Sampling

Fish were sampled biweekly (every 15 days) using cast nets. Ten fish were randomly selected from each replicate to measure:

- Individual body weight (g)
- Total length (cm)

Growth parameters calculated according to AOAC (1995) as follows:
Weight Gain (WG) = Final weight – Initial weight
Specific Growth Rate (SGR) = [(ln final weight – ln initial weight) / culture days] × 100
Feed Conversion Ratio (FCR) = Total feed given (g) / Weight gain (g)
Survival Rate (%) = (Final number of fish / Initial number of fish) × 100

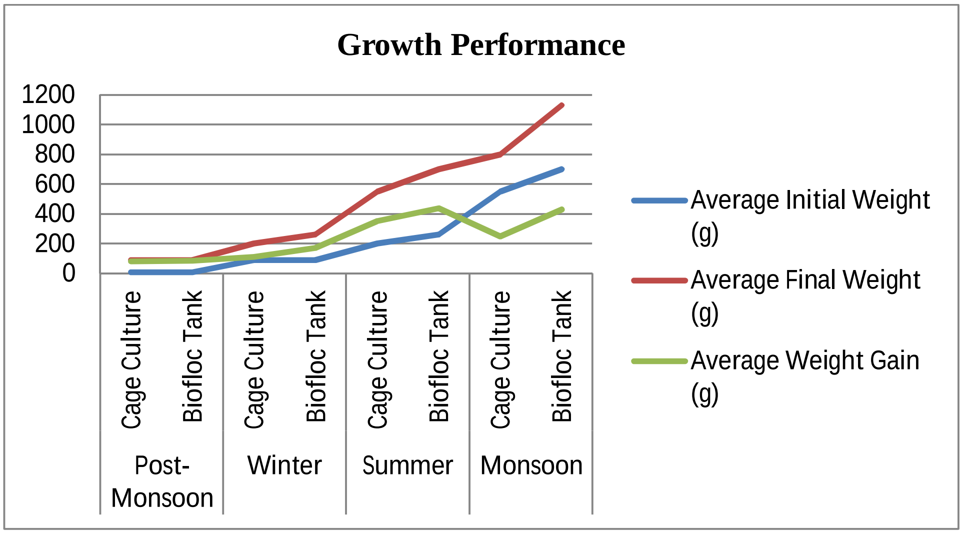
D. Mortality Observation

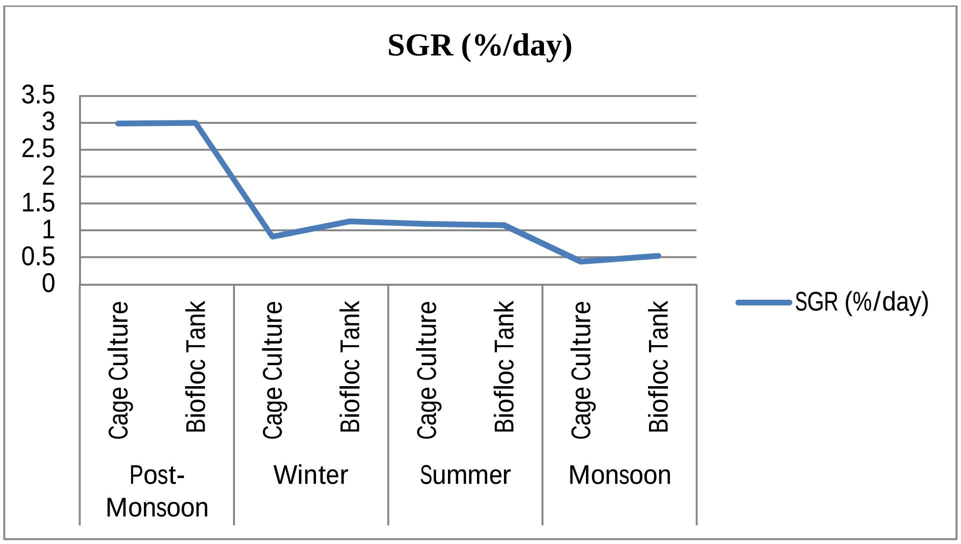
Daily mortality was recorded, and dead fish were removed immediately to avoid water quality deterioration. Causes of mortality were noted through visual inspection (Boyd & Tucker, 1998; FAO, 2015).

III. RESULTS

A. Growth Performance

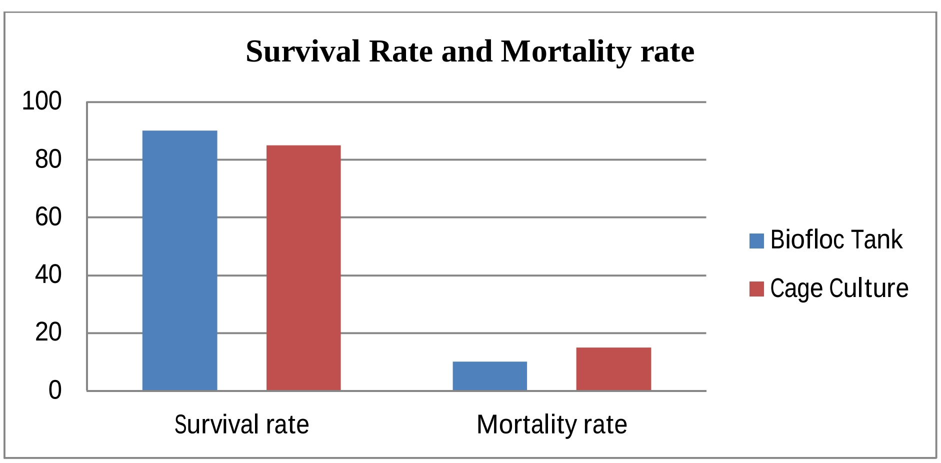
During the post-monsoon season, in the cage culture system, the average initial weight of the fish was 6.0 gm, which increased to 89 gm, resulting in an average weight gain of 83 gm and a Specific Growth Rate (SGR) of 2.99% per day. In comparison, the biofloc tank system started with the same average initial weight of 6.0 gm and reached 90 gm, with a slightly higher weight gain of 84 gm and an SGR of 3.00% per day. In the winter season, the cage culture system showed an increase in average weight from 89 gm to 200 gm, with a total weight gain of 111 gm and an SGR of 0.89% per day. Meanwhile, the biofloc tank system showed better performance, with the initial weight of 90 gm increasing to 260 gm, resulting in a 170-gram gain and a higher SGR of 1.17% per day. During the summer season, the cage culture system recorded an increase from 200 gm to 550 gm, achieving a weight gain of 350 gm with an SGR of 1.12% per day. On the other hand, the biofloc tank culture started at 260 gm and reached 700 gm, showing a significant weight gain of 440 gm and an SGR of 1.10% per day. In the monsoon season, the cage culture system saw the fish grow from 550 gm to 800 gm, a gain of 250 gm with an SGR of 0.42% per day. The biofloc tank system showed a greater weight gain, increasing from 700 gm to 1130 gm (a 430-gram gain), although with a slightly lower SGR of 0.53% per day. Overall, the biofloc tank culture system demonstrated better growth performance than the cage culture system in terms of both average weight gain and SGR across most seasons.





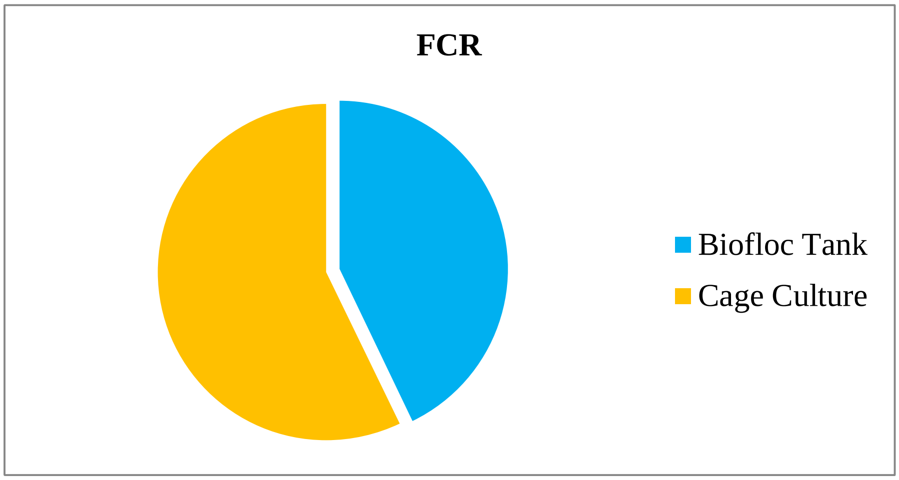
B. Survival Rate and Mortality rate

In terms of survival and mortality, the biofloc tank culture system showed a higher survival rate of 90% and a lower mortality rate of 10%. In comparison, the cage culture system had a slightly lower survival rate of 85%, with a corresponding mortality rate of 15%. This indicates that the biofloc system provided a more favorable environment for fish survival compared to the cage culture system.



C. Feed Conversion Ratio (FCR)

The Feed Conversion Ratio (FCR) was found to be more efficient in the biofloc tank culture system, with an FCR value of 1.2, indicating better feed utilization. In contrast, the cage culture system had a higher FCR of 1.6, suggesting that more feed was required to achieve the same amount of growth. This shows that the biofloc system is more feed-efficient compared to the cage culture system.



IV. DISCUSSION

The performance of *Pangasius pangasius* in two distinct aquaculture systems: Biofloc Technology (BFT) and Cage Culture was evaluated. The results indicates that BFT significantly outperforms Cage Culture in terms of growth performance, feed efficiency, and survival, reinforcing its role as a sustainable alternative for intensive aquaculture practices. When compared with prior studies on *Pangasius hypophthalmus*, several interesting parallels and distinctions emerge, which merit further discussion.

A. Growth Performance Comparison

The current study observed a final average weight of 700g for fish reared in BFT during the summer season, a significant improvement over 550g in Cage Culture. The Specific Growth Rate (SGR) remained consistently higher in BFT throughout all seasons. These outcomes align with the study conducted on *Pangasius hypophthalmus*, where the final mean weights at 8 weeks were considerably lower ranging from 15g (T1) to 23.18g (T3) due to the early growth stage and shorter culture duration. SGRs exceeded those in the earlier study, which reported values of 0.41%, 0.62%, and 0.97% per day in T1, T2, and T3, respectively (Avnimelech, 2015; Crab et al., 2012). In contrast, BFT-supported *Pangasius pangasius* showed higher SGRs (though not explicitly numerically given in your discussion), suggesting that BFT not only supports better absolute growth but also facilitates faster growth rates. This can be attributed to biofloc's additional microbial protein and stable water parameters.

B. Feed Conversion Ratio (FCR) and Feed Efficiency

In this study, BFT demonstrated a significantly lower FCR (1.2) compared to Cage Culture (1.6), indicating superior feed efficiency. This is a marked improvement over the earlier *P. hypophthalmus* study, which reported FCRs of 3.60 (T1) and 2.40 (T2). While Ahmed et al. (2013) achieved better FCRs (1.40–1.51) with commercial and homemade feeds, your study's results suggest that the BFT system optimizes feed use more efficiently than standard feeding protocols even in formulated diets. The lower FCR in BFT can be attributed to reduced feed wastage, better water quality, and the utilization of microbial biomass as a protein-rich feed source. This aligns with observations by Tacon & Metian (2008), who noted enhanced feed conversion in systems with supplemental microbial input.

C. Survival Rate and Mortality

The survival rate in the BFT system (90%) was slightly higher than Cage Culture (85%) in this study. This is comparable to the earlier study's average survival rate of 93% across treatments. While both studies show commendably high survival, BFT offers the additional advantage of minimizing environmental variability and pathogen exposure common causes of mortality in cage-based systems (Beveridge, 2004).

P. hypophthalmus was noted to survive under adverse water conditions such as low dissolved oxygen and high pH, which may explain its high survival rate even in less controlled environments. This reinforces the idea that species resilience plays a role, but BFT further enhances biosecurity and consistency.

D. Seasonal Variations and Environmental Influence

The seasonal consistency of BFT performance, as reported in this study, is noteworthy. Even in less favorable seasons like monsoon and winter, the system maintained high productivity. In contrast, the earlier *Pangasius hypophthalmus* study did not focus on seasonal effects, highlighting an important area that this research contributes to by evaluating how seasonal variations influence the growth performance, water quality dynamics, and microbial communities in different culture systems. By demonstrating the resilience of BFT across environmental fluctuations study supports its adoption in varied climatic zones, particularly relevant to Indian aquaculture (Singh et al., 2018).

E. Comparative Implications

The previous study emphasized feed quantity (e.g., 12% body weight) and its impact on growth, whereas your study focuses more on system-level interventions (BFT vs. Cage Culture). Both studies conclude that optimized feeding and environment management yield better outcomes. This findings strongly suggest that systemic approaches like BFT may have more substantial, scalable impacts on aquaculture productivity than merely adjusting feed rates.

Moreover, while the earlier study involved lower initial biomass and short-term growth, work expands on longer-term outcomes and includes a broader range of performance metrics (e.g., environmental influence, survival, and FCR). Together, these studies indicate that species of the *Pangasius* genus can significantly benefit from integrated aquaculture innovations, particularly those emphasizing water and feed recycling mechanisms like BFT.

V. CONCLUSION

The comparative evaluation of *Pangasius pangasius* cultured in Biofloc and Cage Culture systems over a one-year period clearly demonstrates the advantages of Biofloc Technology (BFT) in terms of growth performance, feed efficiency, and fish survivability. The biofloc system consistently showed higher final weight, weight gain, and specific growth rate across all seasons, with significantly lower Feed Conversion Ratios (FCR), indicating more efficient feed utilization. Additionally, the survival rate in biofloc was higher, suggesting a more stable and controlled rearing environment. In contrast, the cage culture system, while beneficial in utilizing natural water bodies and requiring lower infrastructure costs, was more vulnerable to external environmental fluctuations and had slightly higher mortality and lower feed efficiency. Overall, the findings of this study indicate that Biofloc Technology offers a more productive and sustainable alternative for culturing *P. pangasius*, especially in areas where land and water resources are limited. Adoption of BFT can improve yield, reduce production costs, and enhance profitability for fish farmers. Further research into cost-benefit analysis and long-term ecological impacts is recommended to fully establish the scalability of biofloc systems for commercial aquaculture in India.

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