Evaluating the performance of Biofloc technology in enhancing the aquaculture productivity in Bihar

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Abstract - The study has estimated the effectiveness of the Biofloc Technology (BFT) in enhancing the productivity of aquaculture within indoor environment in the state Bihar and *Clarias batrachus*. An experiment was carried out of a comparison between a BFT-based system and a traditional culture system using a 90-day period. Major factors like quality of water, growth performance, feed conversion ratio (FCR), and survival rate and immunity levels of the fish were measured. Findings indicated that BFT system was having a large effect on improving the quality of water in reducing the levels of ammonia, nitrite, and nitrate and increasing the level of dissolved oxygen. The growth per unit of fish cultivated in the BFT system was increase, specific growth rate (SGR) was superior, FCR was better, and the survival rates were greater. There was also an increase in immunological markers such as the hemoglobin, WBC levels, levels of serum lysozyme activity and protein. Moreover, biofloc biomass was quite rich in crude protein thus signifying its importance as a form of supplementary feed. BFT also gave better benefit-cost ratios economically, even though initial inputs were more. In the findings, the potential of BFT has been noted as a means of sustainable and cost-effective solution of aquaculture development in sections of resource-constrained regions such as Bihar.

Keywords- Biofloc Technology, *Clarias batrachus*, Fish growth, Aquaculture, and Bihar.

I. INTRODUCTION

The swift expansion of the total population of humans on Earth has resulted in a substantial rise in food demand. To satisfy this demand, the augmentation of animal-based protein production, the primary source of nourishment for consumption by humans, is essential. Aquaculture represents the optimal source of protein from animals, capable of being produced at minimal cost and with remarkable speed. The enhancement of aquaculture production by both horizontal and vertical expansion results in a significant rise in pollutants in the adjacent environment [1]. The growing awareness of environmental challenges has resulted in an increased need for environmentally friendly management and customs of culture. Furthermore, the substantial utilization of fish oils and fish meal in farming has exerted considerable strain on the ecosystem [2]. Water consumption is another essential factor. In the 1980s, researchers acknowledged the significance of water exchange in alleviating many diseases, including epidemics, in shrimp aquaculture operations [3]. Consequently, numerous shrimp producers have implemented strategies to minimize water exchange, adopting a more prudent approach to water consumption [4].

The success of aquaculture is wholly reliant on both the biological and physical characteristics of water. Therefore, water quality regulation is essential for optimal pond managing [5]. Certain research indicates that the nitrogen (N) to carbon (C) ratio in aquaculture water should be regulated through the effective application of bio flocthe BFT. Consequently, the BFT constitutes a combined structure and the overall effectiveness of this system, contingent upon the biotic composition of biofloc and the concentration of suspended particles, is assessed using Imhoff cones [6].

Carbon sources are vital for sustaining an effective and productive biofloc environment. They supply energy for microbial proliferation and facilitate the decomposition of organic material [7]. The use of carbon sources facilitates the formation of bioflocs, which act as a natural supply of high-quality nutrition for aquatic species. Moreover, carbon sources facilitate the elimination of detrimental nitrogenous molecules, including ammonia and nitrite, via the method of denitrification [8].

Various categories of carbon sources are applicable in biofloc systems. Each source possesses distinct features and nutrient profiles, which might affect the overall efficacy of the system. Below are frequently utilized carbon sources: Cornstarch, Molasses, Rice Bran, Wheat Bran, Vegetable Residues, Glycerol, Methanol, Acetic Acid, Sugar [9].

BFT is an innovative alternative aimed at fostering ecologically sustainable practices in aquaculture production. This method promises to provide environmental and economic advantages by minimizing water usage and effluent releases, lowering reliance on synthetic feed, and improving biosecurity [10,11], The notion of Byzantine Fault Tolerance (BFT) has been acknowledged since the 1970s. Substantial research on the development and use of this technology has been undertaken since the 1990s, producing encouraging outcomes [12]. This method seeks to improve water quality, avert illnesses, and enable waste management in intensive aquaculture systems [13].

1.1. Species appropriate for growing utilizing biofloc technology.

- Shrimps: Litopenaeus vannamei, Penaeus monodon, Macrobrachium rosenbergii, Litopenaeus stylirostris, and Fenneropenaeus merguiensis
- Fish: Indian Major Carps, Pangasius, Tilapia, and Exotic Major Carps, among others [14].

1.2. Advantages of biofloc technology: -

- ✓ Environmentally sustainable culture system.
- ✓ Enhances land and water utilization efficiency.
- ✓ Minimal or no water exchange.
- ✓ Increased productivity.
- ✓ Enhanced biosecurity.
- ✓ Mitigates water pollution.
- ✓ Economically viable.
- ✓ Alleviates pressure on capture fisheries, utilizing less expensive food fish and bycatch for feed formulation [15].

1.3. Disadvantages of biofloc technology: -

- ✓ Elevated energy demand for mixing and aeration.
- ✓ Necessity for alkalinity supplementation.
- ✓ Heightened pollution risk due to nitrate accumulation.
- ✓ Variable and seasonal efficacy in sunlight-exposed systems.
- ✓ Implementation at the farm level poses risks.
- ✓ The straightforward concept of recycling aquatic organism excreta into feed may deter consumer purchases [16].

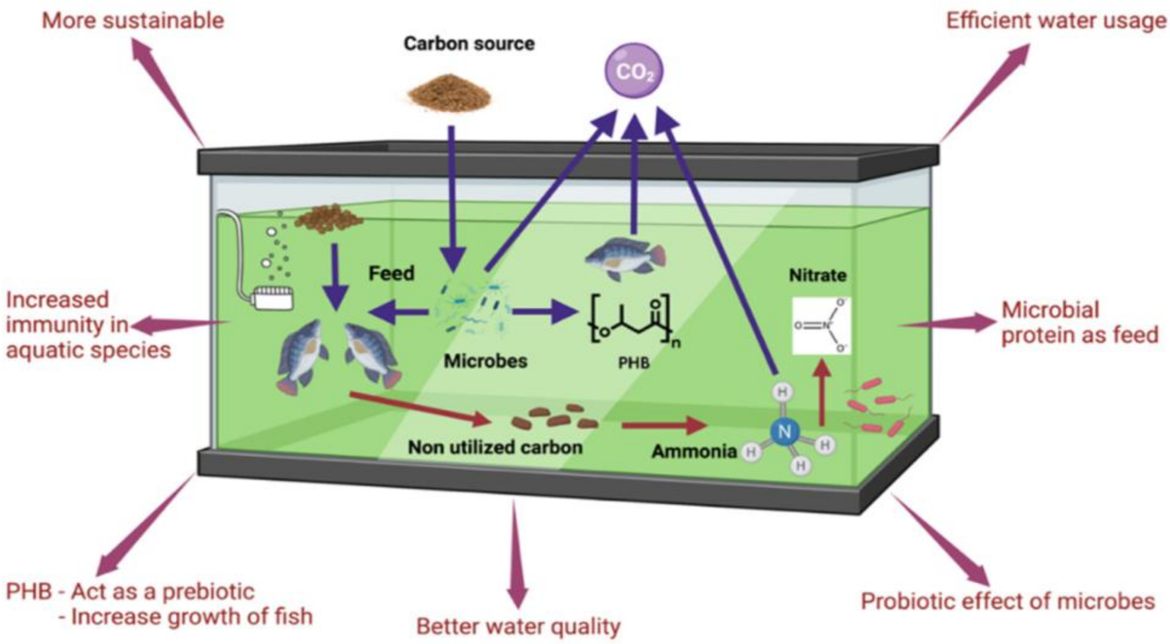

Figure 1: Schematic representation of BFT in aquaculture system and its multifaceted benefits.

Source: Padeniya et al. (2022) [17]

1.4. Objectives of the study

- To evaluate the effectiveness of BFT on growth efficiency, survival rate of aquaculture species (e.g., *Clarias batrachus*) in indoor cultures.
- To determine whether the fish immunity and health are enhanced through probiotic and prebiotic effect of the microbial community created in biofloc and fish health.
- To compare the water quality parameters (e.g., ammonia, nitrate, dissolved oxygen, pH) between the biofloc and the traditional system of aquaculture.

II. REVIEW OF LITERATURE

Bossier and Ekasari (2017) indicated that BFT has the capability to significantly enhance aquaculture productivity while lessening environmental footprint in support of sustainable development objectives. They pointed out its promissory potential for hybridization with other food systems to leverage greater resource efficiency. Nonetheless, they noted that BFT is presently in its nascent stage and needs more research on nutrient recirculation, microbial function, and immunological advantages. The authors also indicated the requirement of training farmers to guarantee successful adoption and use of the technology [18].

Kumar et al., (2022) examined the function of specific microbial inoculums in improving biofloc growth and aquaculture performance. Three microbial mixtures, including Bacillus subtilis, Pseudomonas spp., and Saccharomyces cerevisiae, were tested and proved that Group 2 (including B. subtilis, P. fluorescens, and S. cerevisiae) effectively improved the water quality, gut microbiota, and growth of Heteropneustes fossilis. Increased digestive enzyme activities, immune gene expression (transferrin, IL-1β, C3), antioxidant response (CAT, SOD), and hormonal levels (T3, T4, IGF1) were recorded. The results justify the prospect of customized microbial inoculums in maximizing biofloc systems for sustainable fish culture [19].

Wang et al. (2022) published the first high-quality, chromosome-level genome assembly of blue catfish (Ictalurus furcatus), which solves a major drawback in hybrid catfish transcriptomic and epigenomic research because of low correspondence with the channel catfish genome. The 841.86 Mbp assembled genome showed 30,971 protein-coding genes and exhibited strong completeness and continuity. Phylogenomic analysis revealed a split with channel catfish approximately 9 million years ago, with significant SNP diversity among leading blue catfish strains. Also, enlarged immune-related gene families were found, potentially conferring disease resistance. This genome resource facilitates sophisticated genetic studies, such as SNP discovery, gene editing, and hybrid breeding in aquaculture [20].

Kimera et al. (2024) investigated the possibility of bringing together saline aquaculture wastewater with fish and crop production to mitigate freshwater deficiency in arid areas. The research evaluated the effect of different levels of salinity on sorghum growth and nutritional quality, together with the survival and well-being of Pangasianodon hypophthalmus. Although increased salinity impaired fish performance above 10,000 ppm, growth and forage quality of sorghum were unaffected across treatments. The results indicate that incorporating fish rearing in water with a salinity of up to 5000 ppm with sorghum culture could be an efficient solution for sustainable utilisation of resources in water-scarce environments [21].

Although it is being increasingly well known and its advantages in enhancing the functioning of aquaculture production in the world are consistently being proved, there is not enough specific data concerning its efficiency in the socio-ecological environment of Bihar, state which has great potential in fish farming and substantial rural population highly dependent on fish farming in inland area. A major part of the existing literature reflects the efforts of carrying out most of the studies under controlled experimental conditions or in areas having distinct climatic, hydrological, and economic characteristics.

Besides, national agencies and implemented the BFT training and pilot projects in Bihar, but the empirical analysis of BFT effect on fish growth, water parameters, and feed conversion and acceptability by farmers was not extensively done. Moreover, there exist limited literatures that provide comparison of the various sources of carbon (e.g., jaggery, molasses, wheat flour, rice bran) and their efficiency towards stimulating microbial activity and fish productivity under native conditions. This causes an urgent knowledge gap on maximization of BFT protocols applicable to various farming communities in Bihar.

III. METHODOLOGY

The experiment was performed at a preset indoor fish farm facility in the state of Bihar lasting a period of 90 days (January 2025- March 2025). Completely Randomized Design (CRD) having two treatment systems in triplicate:

BFT System (Treatment): Indoor 1,000-L tanks having Biofloc, continuous ventilation, and No Water Exchange.

Control (Traditional): Same type of tanks with the regular culture, moderate water exchange (20% weekly).

Each treatment had 3 replicates, totalling 6 tanks.

In a bid to determine the efficiency of BFT, a series of experiments was conducted by raising *Clarias batrachus* during controlled 90 days of indoor experiments in the state of Bihar. These indicators of key interest measured were water quality parameters (ammonia, nitrite, dissolved oxygen, pH), growth performance measures (specific growth rate, feed conversion ratio, weight gain, survival rate), hematological and immunological parameters (hemoglobin, white blood cell count, lysozyme activity, serum protein), nutritional composition of biofloc and economic feasibility. To provide an optimal carbon to nitrogen ratio, carbon sources, molasses, jaggery, wheat flour and rice bran were locally obtained to maintain the biofloc systems. Studies conducted earlier have demonstrated that the presence of complex carbon source such as jaggery and rice bran has increased bioflc stability, microbial activity, and bird water quality as well as fish growth performance.

3.1. Species and stocking protocol

Species: *Clarias batrachus* (desi magur catfish)

Average weight: 1.7gm

Stocking density: 150 fish per 1000 L tank

3.2. Biofloc System Set-up

Continuous aeration systems were installed in biofloc tanks to conduct sufficient levels of dissolved oxygen and suspend floc particles. In various treatment units, carbon materials like molasses, jaggery, wheat flour or rice bran were added in order to maintain desired carbon-to nitrogen (C: N) ratio. Biofloc tanks were not drained in order to encourage recycling of microorganisms.

3.3. Water Quality Monitoring

Water sampling was done every week, and the major physicochemical parameters were measured:

- Temperature
- pH
- Dissolved oxygen (DO)
- Total ammonia nitrogen (TAN)
- Nitrite and nitrate

These parameters were analyzed by the use of standard laboratory procedures.

3.4. Growth Performance Assessment

The performance of growth was measured through collection of fish regularly, a fortnight, and measuring:

- Gain of body weight
- SGR
- FCR
- Survival rate

End values were determined at the end of the 90 days culture period.

3.5. Health and Immunity analysis

At the start and finish of the experiment blood samples were taken at random on the fish to determine:

- Hemoglobin concentration
- White blood cells count.
- Serum proteins concentrations
- Lysozyme activity

These were the showings of immune stimulatory effect of biofloc.

3.6. Composition Bioflocs Analysis

Biofloc samples were taken in the tanks and analyzed with regards to:

- Crude protein
- Lipid content
- Moisture
- Ash content

This analysis has been carried out to determine the nutritional value of the floc as supplementary source of feeds.

IV. RESULT

The findings of this study depicted a thorough comparison and a contrast between BFT system and the customary aquaculture system concerning water quality, fish growth performance, health condition, biofloc aggregates, and economic viability. A total of 90 days culture period was taken to collect data which was analysed to calculate effectiveness of BFT in indoor culture conditions of Bihar. Results reflect that significant alterations in most of the crucial parameters have been observed, which shows that biofloc systems can be used to improve the productivity of aquaculture in limited-resource settings. The results have however been tabulated below to make comparison and analysis easy.

4.1. Water Quality Parameters

Monitoring of weekly physicochemical parameters indicated that the Biofloc system had more stable and beneficial water quality than the conventional system at all times.

Table 1: Water quality parameters observed in biofloc and traditional system (mean ± SD)

Sr. No.	Parameters	Biofloc system (mean ± SD)	Traditional system (mean ± SD)
1	Temperature (^{0}C)	26.5 ± 0.6	26.1 ± 0.8
2	pH	7.6 ± 0.2	7.3 ± 0.3
3	Dissolved oxygen (mg/L)	6.4 ± 0.4	5.7 ± 0.5
4	Total ammonia nitrogen (mg/L)	0.38 ± 0.10	0.70 ± 0.15
5	Nitrite (mg/L)	0.21 ± 0.06	0.36 ± 0.09
6	Nitrate (mg/L)	8.9 ± 1.5	13.4 ± 2.0

Interpretation: The table shows that biofloc tanks had better physico-chemical conditions; due to higher DO and pH value and reduced ammonia, nitrite, and nitrogen nitrate levels. The high TSS scores prove that there is active microbial activity present. This corresponds to efficient recycling of nitrogen and enhancements in system stability experienced with BFT.

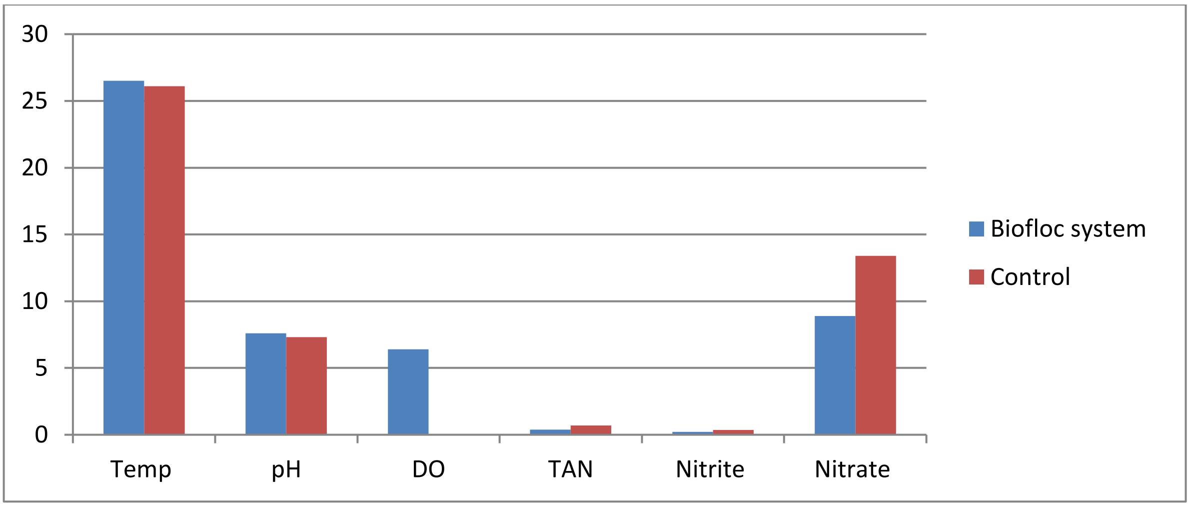

Figure 2: This graph visually explains how BFT works by converting nitrogenous waste into microbial biomass through heterotrophic bacterial activity. It demonstrates key benefits such as Improved water quality, microbial protein production, feed effieiency, and enhanced fish health, all of which contribute to sustainable aquaculture practices.

4.2. Growth Performance of *Clarias batrachus*

During the 90-day culture period, fish cultured under the Biofloc system presented improved growth performance and feed efficiency.

Table 2: Growth performance of *Clarias batrachus* in biofloc vs. traditional system

Sr. No.	Growth Parameters	Biofloc system	Traditional system
1	Initial weight (g)	1.7	1.7
2	Final weight (g)	42.1 ± 1.3	30.7 ± 1.5
3	Weight gain (g)	40.4	29.0
4	SGR (%/day)	3.74 ± 0.10	3.01 ± 0.12
5	FCR	1.48 ± 0.06	1.86 ± 0.08
6	Survival rate (%)	94.2 ± 2.0	86.3 ± 2.5

Interpretation: Fish in biofloc group had improved growth: they had increased final weight, a rapid growth rate, reduced FCR and also increased survival. This displays that the biofloc system allows growth that is more efficient and has optimal feed utilization.

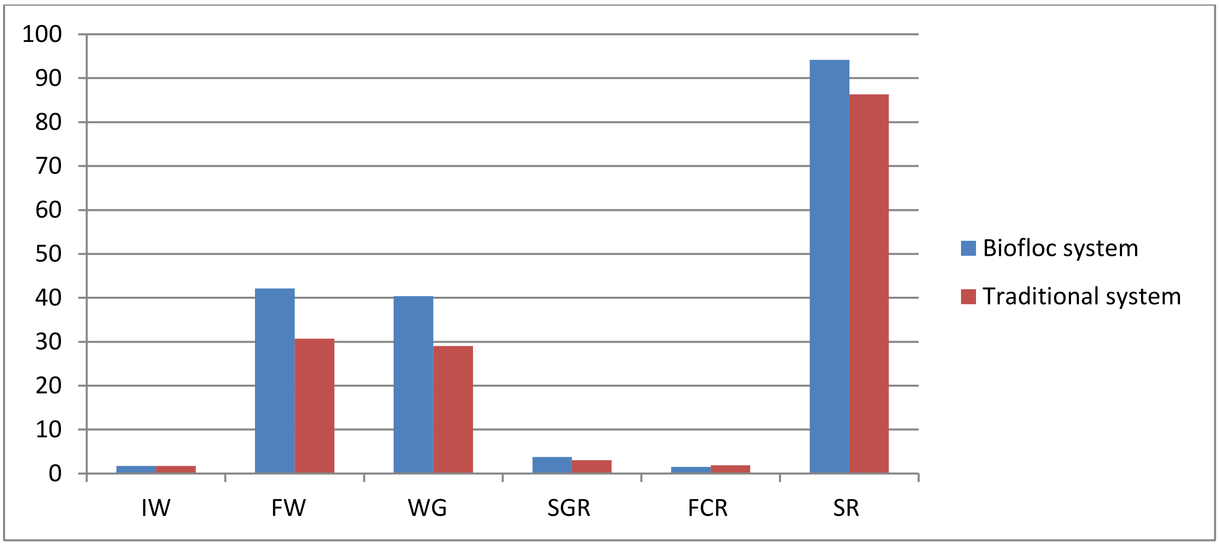

Figure 3: This bar graph shows enhanced fish growth in the biofloc system. The parameters of final weight, weight gain, and SGR were greater, and FCR was lesser compared to the conventional system. Survival rates were also greater in the biofloc group, which reflects more efficient and healthier conditions for growth.

4.3. Health and Immunity Indicators

Immune and hematological parameters revealed an increased physiological status in fish raised under Biofloc conditions.

Table 3: Health and Immunity Indicatorsof fish in biofloc vs. traditional system

Sr. No.	Parameters	Biofloc system	Traditional system
1	Haemoglobin (g/dL)	10.4 ± 0.5	9.0 ± 0.4
2	WBC count ($\times 10^3$/mm^3)	46.2 ± 3.1	38.5 ± 2.7
3	Lysozyme activity (U/mL)	5.70 ± 0.35	4.35 ± 0.32
4	Serum protein (g/dL)	4.75 ± 0.25	3.90 ± 0.28

Interpretation: These increased values of hemoglobin, white blood cells, and lysozyme activity indicate that biofloc-reared fish possessed more vigorous immune responses and enhanced physiological resistance.

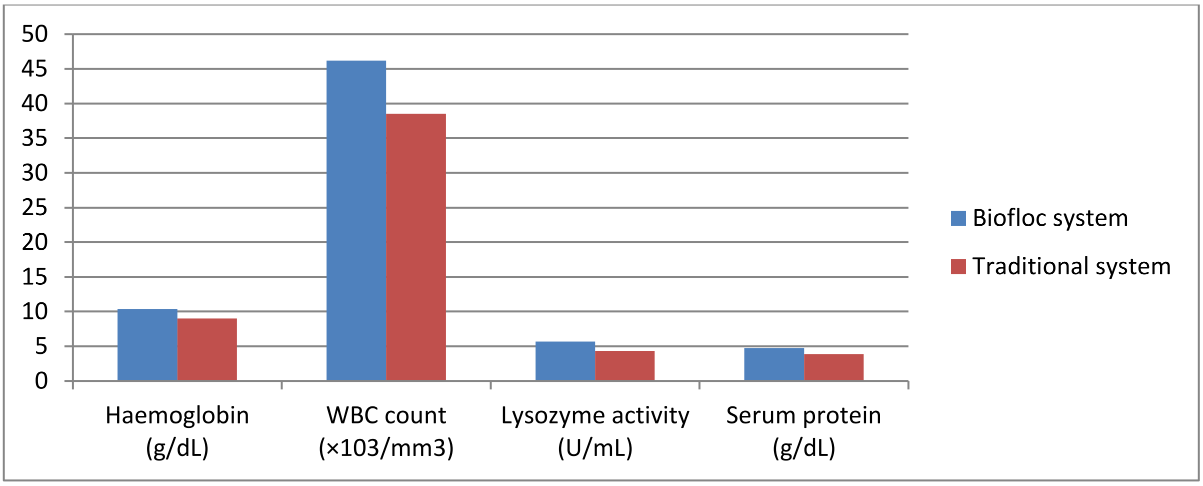

Figure 4: Biofloc-reared fish had increased hemoglobin, WBC count, lysozyme activity, and serum protein. These improved immune markers indicate that biofloc systems enable more robust physiological responses, presumably because of the probiotic action of microbial flocs.

4.4. Proximate composition of Biofloc

Biofloc samples were nutritionally dense and contained the following composition:

Table 4: Proximate composition of biofloc biomass

Sr. no.	Component	Mean ± SD
1	Crude protein (%)	28.6 ± 1.1
2	Crude lipid (%)	5.9 ± 0.8
3	Moisture (%)	9.2 ± 0.9
4	Ash (%)	13.4 ± 0.7

Interpretation: The biofloc biomass was a good supplementary feed source, full of protein and nutritious compounds.

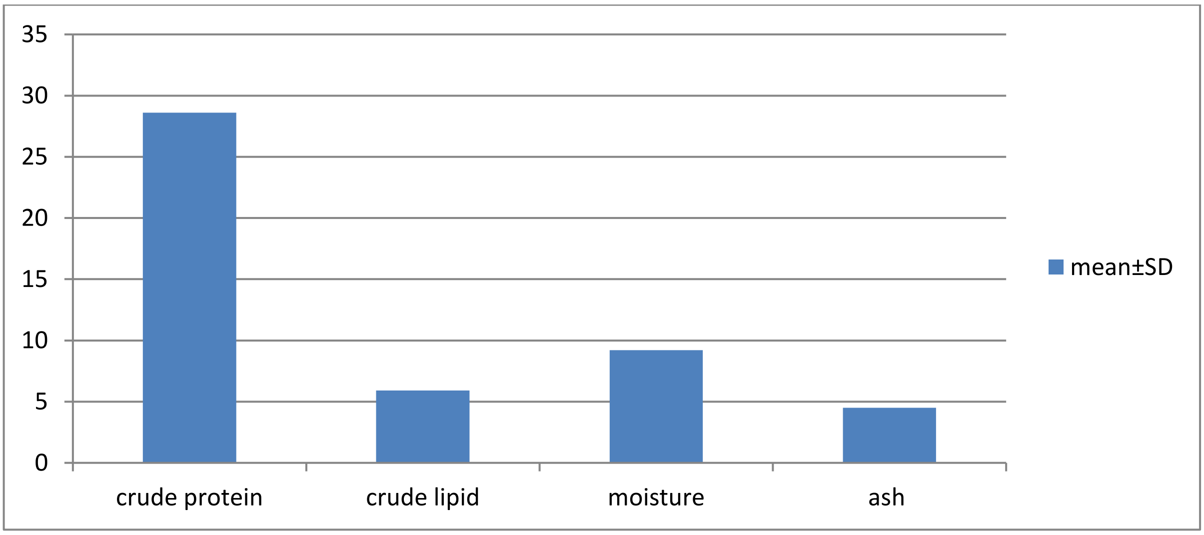

Figure 5: The graph indicates that biofloc is high in crude protein (~28.6%), together with lipids, moisture, and ash. The composition indicates its use as a supplementary feed rich in protein, which decreases the dependence on commercial feed and enhances cost-effectiveness in aquaculture.

V. DISCUSSION

The results of this research are evidence of positive results about the success of BFT in the valley of Bihar. Water quality enhancement in the biofloc system as witnessed by reduction in ammonia, nitrite, and nitrate concentration as well as dissolved oxygen is attributed to significant role played by microbial community in nitrogenous waste assimilation and ecological balance. It is in line with findings by Sohel et al. (2023) as these authors realized a comparable decline in harmful nitrogenous substances in the Heteropneustes fossilis raised in BFT systems, resulting into more consistent and sustainable culture modes [22]. Similarly, the study of Emerenciano et al. (2017) showed that biofloc-based tanks have consistently performed better modality, showing a distribution of water quality, especially by recycling nitrogen compounds by heterotrophic bacteria [23].

The biofloc group recorded significant improvement in growth performance characterized by a stronger final body weight, weight gain, a better SGR, and a lower FCR. It is possible to refer these growth advantages to the improvements in the quality of water, as well as biofloc biomass nutritional value. Equally good performance has been reported by Sasmal et al. (2024), who showed much better growth and feed conversion in *Clarias batrachus* which were cultured using freshwater biofloc systems [24]. Other authors also noted significant positive changes in the growth parameters of Asian stinging catfish in a biofloc environment and support this system due to its adaptability to multiple freshwater species.

Economically, the biofloc system was more cost effective as compared to the traditional, although the input costs incurred were slightly high owing to aeration and carbon supplements. The biofloc tanks provided better harvest, gross returns, and a much better benefit-cost ratio (BCR), as well as resource utilization. Such results align with those of the study by Sasmal et al. (2024) and Sohel et al. (2023) who noted the potential of biofloc systems to serve as economic solutions to the small- and medium-scale aquaculture enterprises [24,22].

Collectively, these data imply that BFT has a great potential in enhancing aquaculture productivity in resource-poor areas like in Bihar. They confirm the promise of biofloc as a sustainable method of fish growth, water quality, immunity, and profitability in terms of intensive conditions. To fully harness the benefits of biofloc systems, as stressed by Raza et al. (2024), in their recent review, optimization of the C:N ratio and the microbial dynamics is put forward as central [25]. Although the current study illustrates the fundamental advantages of BFT, future studies may be done to assess the comparative effectiveness and relative efficacies of various carbon sources (e.g., molasses, rice bran, jaggery), the application of specific probiotics, and the hybridization with digital monitoring to track real-time system optimization. Generally, the study will provide useful evidence to promote the spread of biofloc based aquaculture in Eastern India and will have a practical input on the dissemination of the technology among fishermen in the rural areas.

VI. CONCLUSION

This research verifies that BFT is an efficient and environmentally friendly approach to enhancing aquaculture productivity in Bihar. In contrast to conventional systems, BFT had improved water quality, greater growth, and survival rates of *Clarias batrachus*, greater feed efficiency, and improved fish immunity.

Biofloc systems lowered injurious nitrogen and yielded a protein-rich microbial biomass, which was a useful supplementary feed. Although initial capital costs were higher, the system was economically advantageous because of increased yields and improved resource utilization.

In general, BFT is suited to poor-resource regions such as Bihar and presents a feasible, sustainable solution for small-scale fish farmers. Additional research should be conducted to maximize carbon sources, analyze seasonal effects, and incorporate digital monitoring for enhanced efficiency.

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