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Biofloc Technology: Optimizing Aquaculture through Microbial Innovation

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Review Article

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ABSTRACT

Biofloc technology (BFT) is an innovative approach in aquaculture that provides substantial advantages for the implementation of sustainable and efficient aquaculture techniques. BFT entails the careful management of water quality and the provision of nutrients to cultivated aquatic organisms by adding carbon sources in a balanced manner. This supports the formation of advantageous microbial communities. The biofloc is an assemblage of organic material and microbes that is abundant in proteins. It functions as a natural source of food for species such as tilapia and prawns, hence decreasing the reliance on costly commercial feeds. This self-contained system aids in water conservation, fertiliser recycling, and waste and pollution reduction in comparison to traditional aquaculture methods. BFT additionally boosts the immune system of aquatic species, diminishing the likelihood of prevalent illnesses and fostering overall well-being. Nevertheless, the technology necessitates meticulous control of variables like as carbon-to-nitrogen ratio, water temperature, and dissolved oxygen in order to uphold a stable and fruitful environment. Although there are certain operational difficulties, BFT proves to be a viable approach for attaining sustainable aquaculture by enhancing output while minimising the negative effects on the environment.

Keywords: Biofloc technology; microbial community; carbon nitrogen cycling; biofloc formation; Sustainability.

1. INTRODUCTION

Biofloc technology is an environmentally-friendly method of aquaculture that establishes a self-contained ecosystem within aquaculture systems. The basic objective is to maintain a higher carbon-to-nitrogen ratio in order to stimulate the establishment of a microbial community, mainly consisting of bacteria. This microbial community plays a crucial role in managing water quality and supplying sustenance for the organisms being cultivated. The technology highlights the significance of microorganisms coming together, forming clusters, and optimising the ratio of carbon to nitrogen for the purpose of promoting sustainable aquaculture operations [1]. Biofloc systems are most effective when used with species such as tilapia and prawns that can directly consume the floc and derive benefits from it. Aquaculture technology has become widely popular worldwide, with countries such as South Korea, Brazil, China, Italy, Indonesia, Australia, and India embracing its use. Research institutions around are investigating many uses of biofloc technology, such as energy kinetics, bacterial identification, and economic feasibility. The implementation of biofloc technology in extensive prawn and finfish farms has proven to be effective, resulting in significant increases in production output while minimising the negative effects on the environment. The technology's emphasis on microbial populations, nutrient recycling, and water quality preservation highlights its environmentally benign and economically feasible characteristics [2,3,4].

The development of biofloc technology originated in the 1970s at the French Research Institute for Exploitation of the Sea, Oceanic Centre of Pacific (Ifremer-COP). During this time, research was conducted on many species including *Penaeus monodon, Fenneropenaeus merguiensis, Litopenaeus vannamei*, and *L. Stylirostris* is the scientific name given to a species described by Devi and Kurup [2]. In the late 1980s and 1990s, Israel and the USA, specifically the Waddell Mariculture Centre, initiated research and development efforts in biofloc technology. Their concentration was mostly on tilapia and *L. Vannamei* prawn. The initial implementation of biofloc technology for commercial purposes took place at a farm in Tahiti (French Polynesia) in 1988. The farm utilised 1000m^2 concrete tanks with restricted water exchange and achieved an impressive yield of 20-25 tons/ha/year in two consecutive crops [3]. A farm in Belize, Central America, yielded approximately 11-26 tonnes per hectare per cycle employing poly-lined ponds covering an area of 1.6 hectares. A Maryland-based farm achieved an annual prawn production of 45 tonnes by utilising indoor greenhouse BFT raceways over an area of around 570 cubic metres [5]. Biofloc technology has been effectively implemented in extensive prawn and finfish farms across many regions including Asia, Latin America, Central America, the USA, South Korea, Brazil, Italy, China, India, and other nations. Ongoing research conducted by universities and research centres is dedicated to improving biofloc technology for its application in farming. This research focuses on various aspects such as grow-out culture, feeding technology, reproduction, microbiology, biotechnology, and economics [3,6].

Biofloc technology is acknowledged for its ecologically conscious methodology, which diminishes the pollution burden on water resources by completely eliminating water outflow. Aquaculture may expand in an environmentally friendly way by following

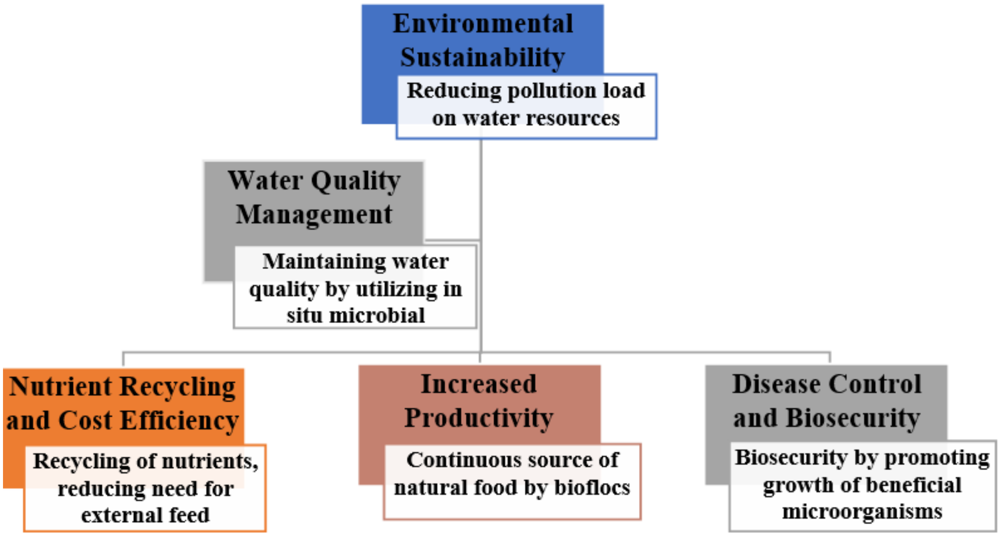

Fig. 1. Biofloc technology holds significant importance in aquaculture due to its numerous benefits and contributions

Table 1. Biofloc technology importance in aquaculture

Aspect	Description	References
Nutritional Value	-Bioflocs are an excellent natural food source for prawns and fish due to their high nutrient content, which includes protein and fats. -The nutritional composition can vary depending on the microbial community and culture conditions	Mansour et al. [11]
Composition	-Macroscopic particles such as diatoms, macroalgae, faeces, exoskeletons, bacteria, invertebrates, and the remains of deceased creatures make up biofloc. -Bacteria and macroaggregates are living organisms that have colonised a water column.	Emerenciano et al. [8]
Benefits	Treats waste from feeding - Provides nutrition through floc consumption - Enhances growth rate and feed conversion ratio - Recycles waste nutrients into fish or shrimp - Maintains water quality	Ogello et al. [12]
Applications	Aquafeed ingredient called "biofloc meal" is used during the following stages: grow-out for tilapia and marine prawns, nursery for freshwater prawns, broodstock development and maturity for fish and shrimp, and freshwater prawn culture.	Addo et al. [13]
Feeding	-Ensure that the feed maintains a C/N ratio between 15 and 25. -Adjust C/N ratio based on TAN and nitrite levels -Use a combination of low and high protein feeds with added carbon sources	Tianjiao et al. [14]
Monitoring	Monitor crucial water quality metrics like oxygen levels, temperature, pH levels, alkalinity, ammonia levels, nitrite levels, and nitrate levels. -Measure biofloc volume using Imhoff cones to evaluate system performance	Panigrahi et al. [15]

sustainable development goals and fostering integrated systems that have minimum impact on the environment [7]. Technology is essential for maintaining water quality by using in situ microbial production to consume excessive nutrients, organic matter, and nitrogen compounds. Implementing this practice aids in maintaining the stability of water quality, minimising the likelihood of contamination, and improving the overall well-being of aquatic ecosystems [8]. Biofloc systems promote nutrient recycling, hence minimising the reliance of external feed inputs. The microbial community effectively transforms nitrogen molecules into microbial protein, resulting in reduced feed expenses, improved feed conversion ratios, and enhanced economic feasibility of aquaculture operations [9,10]. Biofloc technology improves biosecurity by stimulating the proliferation of advantageous microorganisms that outcompete diseases, hence decreasing the likelihood of disease outbreaks in aquaculture systems. This factor enhances the general well-being and long-term viability of aquaculture methods [8].

2. PRINCIPLES OF BIOFLOC FORMATION

2.1 Microbial Dynamics

The microbial dynamics of Biofloc technology revolve around manipulating the carbon-to-nitrogen (C:N) ratio of the culture medium to enhance the growth of a varied microbial community. The community in Biofloc systems consists of bacteria, algae, zooplankton, and fungi. These organisms have important functions in regulating nitrogen levels, preserving water quality, and improving the overall well-being of aquatic species [16]. The microbial interactions in Biofloc systems are distinguished by the processes of assimilation, nitrification, and oxidation. These activities entail the transformation of nitrogen molecules, such as ammonia and nitrite, into a more enduring form, such as nitrate, which can be utilised by aquatic organisms [17]. The structure and role of microbial communities in Biofloc systems might differ based on factors such as ambient conditions, feed content, and operational parameters. Studies have demonstrated that the arrangement and composition of microbial communities in Biofloc systems vary based on the system's unique conditions, and these variations can influence the overall functioning of the system [18,19]. Microbial organisms in Biofloc systems have the ability to break down nitrogen molecules, such as ammonia, and transform them into a more stable form. Ensuring water quality and mitigating pollution in aquaculture systems are crucial tasks that necessitate this process [19].

2.2 Nutrient Cycling

Nutrient cycling is crucial in Biofloc technology since it is responsible for preserving water quality and facilitating the growth of aquatic organisms. The process entails the transformation and reutilization of nutrients within the system to establish a harmonious environment. The first stage of nutrient cycling entails the absorption of nutrients by microorganisms that exist within the system. This include the absorption of nitrogen molecules such as ammonia and nitrite, which are then transformed into microbial biomass [20]. The nitrogen cycle in Biofloc systems include essential activities such as nitrogen fixation, mineralization, nitrification, and denitrification. These mechanisms facilitate the conversion of nitrogen molecules into more stable forms, leading to a decrease in nitrogen levels in the water and the preservation of water quality [21]. Ensuring the correct carbon-to-nitrogen ratio is essential for the efficient cycling of nutrients in Biofloc systems. The ratio mentioned has an impact on the development of microbial communities and the effectiveness of nutrient utilisation in the system [8]. Biofloc systems employ organic carbon sources such as glucose, glycerol, and sucrose to facilitate nutrient cycling. The biofloc bacteria successfully utilise these sources, facilitating the elimination of ammonium and enhancing microbial activity while maintaining optimal levels of dissolved oxygen [22]. The decomposition of organic matter within the biofloc facilitates nutrient recycling, hence decreasing reliance on external feeding and minimising waste generation. The natural process of recycling contributes to the preservation of water quality and the promotion of the growth of aquatic organisms [16].

2.3 Factors Influencing Biofloc Formation

2.3.1 Carbon to nitrogen (C/N) ratio

The ideal C/N ratio for the growth of biofloc often falls within the range of 10:1 to 20:1. It is vital to keep the C/N ratio within this range to encourage the growth of heterotrophic bacteria and stimulate the formation of biofloc. This is necessary for managing water quality and supporting the health and productivity of the cultured aquatic organisms [23,24]. A study conducted by Brazilian researchers discovered the feasibility of decreasing the C/N ratio in

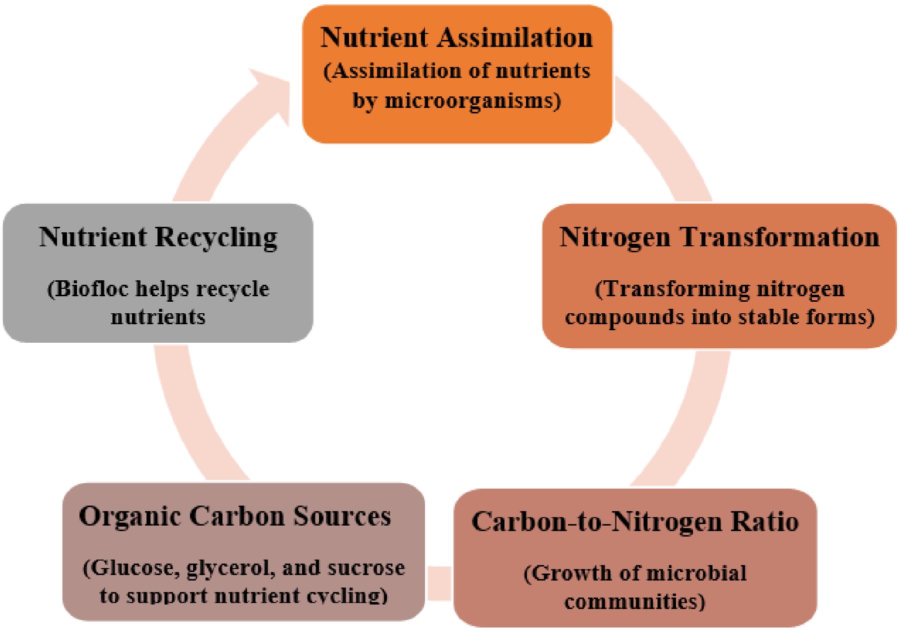

Fig. 2. The process involves the conversion and recycling of nutrients within the system to create a balanced ecosystem

biofloc cultures to a minimum of 7.5:1. This reduction effectively minimises water use and the generation of total suspended solids, resulting in significant savings of capital and resources. According to Saha et al. [24], a C/N ratio of 12.5:1 is optimal for establishing a mixed heterotrophic-autotrophic biofloc system. This ratio ensures a good balance between water quality, solids production, and prawn performance. A separate study shown that C/N ratios of 15:1 and 20:1 had a significant ($p<0.05$) effect in reducing levels of total ammonia nitrogen (TAN) and nitrite-nitrogen (NO2-N) when compared to a lower C/N ratio of 5:1 and the control group without biofloc [23].

2.3.2 Carbon sources

The introduction of organic carbon sources such as glucose, starch, and glycerol can have an impact on the structure and composition of the microbial community in the biofloc. Additionally, it can lead to a decrease in the presence of harmful bacteria such Vibrio spp. [25]. The substances included are molasses, glycerol, dextrose, sodium acetate (CH_3COONa), complex carbohydrates, and mannanoligosaccharides (MOS). The utilisation of these carbon sources is vital in stimulating the proliferation of heterotrophic bacteria, which play a pivotal role in the development of biofloc and the overall effectiveness of biofloc technology in aquaculture systems [26].

2.3.3 Nitrifying bacteria

Nitrifying bacteria are essential in biofloc technology (BFT) aquaculture systems since they facilitate the nitrification process, converting harmful ammonia into nitrate. The growth of these bacteria is facilitated by the natural occurrence of ammonia and nitrite, as well as the buildup of flocculated materials in the biofloc system. The process of nitrification is crucial for preserving water quality and facilitating the development of cultured aquatic organisms in BFT. The conversion is carried out by autotrophic nitrifying bacteria, specifically the ammonia-oxidizing bacteria and the nitrite-oxidizing bacteria. The ammonia-oxidizing bacteria, such as Nitrosomonas, Nitrosococcus, Nitrosospira, and Nitrosolobus, transform ammonia into nitrite. On the other hand, the nitrite-oxidizing bacteria, such Nitrosovibrio, Nitrobacter, Nitrococcus, and Nitrospira, metabolise nitrite into nitrate. These bacteria flourish in many conditions and play a vital role in effectively eliminating ammonia nitrogen in biofloc systems, hence enhancing water quality management and system productivity [8,27,28].

2.3.4 Water quality parameters

It is necessary to closely monitor and maintain factors like as temperature, salinity, alkalinity, pH, dissolved oxygen, suspended particles, and orthophosphate within optimal limits in order to ensure proper biofloc production and operation

[25]. To sustain the aerobic microbial processes in the biofloc system, it is crucial to maintain DO levels at approximately 5 ppm, as stated by Ekasari and Maryam [29]. It is crucial to keep the pH level between 6.5 and 9.0 to provide optimal conditions, as changes in pH can impact both the creation of biofloc and the physiological processes of the organisms being cultivated. Sufficient alkalinity, usually at a minimum of 20 ppm, is required to counteract pH fluctuations and uphold a consistent water environment [9]. It is essential to keep these water quality parameters within their optimal ranges to ensure the effective functioning and performance of biofloc technology in aquaculture.

2.3.5 Microbial community composition

The biofloc technology encompasses a wide range of microorganisms, including bacteria, algae, zooplankton, and fungi, which collectively form the microbial community makeup. Research has demonstrated that the microbial community in biofloc systems include a substantial number of bacteria, eukaryotic species (such as algae and zooplankton), and prokaryotic organisms [19]. The microbial makeup in prawn farms using biofloc technology varied between 48.73% and 73.04% eukaryotic organisms, and between 26.96% and 51.27% prokaryotic organisms. Prokaryotic microbial communities demonstrated greater species richness and variety in comparison to eukaryotic microbial communities. The composition of these microbial communities seems to be impacted by the predation exerted by zooplankton and other associated species, hence emphasising the intricate interplay within biofloc systems [19,17]. Moreover, the makeup of the microbial population can differ depending on factors such as the specific method and carbon source employed in the formation of biofloc. The microbial population of biofloc systems include diverse phyla of bacteria, including Acidobacteria, Actinobacteria, Bacteroidetes, Cyanobacteria, Proteobacteria, and others. In biofloc technology, microalgae have a vital function in the synthesis of nitrogen-related organic compounds such as proteins, hydrocarbons, lipids, and antioxidants through the process of photosynthesis. The chemicals produced by microalgae can improve the production and quality of aquatic organisms in biofloc systems [30,25].

2.3.6 Flocculant additives

The inclusion of mineral-based flocculants, such as clay minerals, can impact the proximate composition of the bioflocs, resulting in alterations in the levels of protein, fat, and ash. Flocculant additions can impact the structure and content of the microbial population in the biofloc system. Flocculant additives have the ability to influence water quality measures, namely the amounts of total suspended particles. The precise influence of flocculant additions on the zootechnical performance, including growth and survival, of cultured aquatic species remains uncertain, as several investigations have demonstrated no noteworthy effect [31].

3. BIOFLOC SYSTEM COMPONENTS

3.1 Tanks and Infrastructure

Efficient biofloc systems typically necessitate specialised infrastructure, including tanks or ponds, aeration systems, and additional equipment to facilitate the production and upkeep of biofloc [15]. Uninterrupted water flow across the whole water column is necessary to stimulate the development of macroaggregates, also known as bioflocs. Biofloc systems commonly employ tanks or ponds with limited or no water exchange, enabling the recycling of nutrients and the preservation of water quality [8]. Aeration systems are essential in biofloc systems since they supply the required oxygen for the microbial community and assist in keeping the bioflocs suspended in the water column. The biofloc system at Chambo Fisheries includes advanced components such as a lamella separator to effectively catch and remove particles, and the ability to modulate the horizontal water velocity to enhance the development and maintenance of biofloc. The infrastructure and design of biofloc systems are intended to minimise both the initial investment and ongoing expenses, while fully utilising the advantages provided by biofloc technology [15,32].

3.2 Aeration Systems

Biofloc technology relies on proper aeration and water circulation to keep biofloc particles suspended in the water column. Diffused air systems that use a variety of diffusers, such as air stones, tubing, or porous hoses, in conjunction with air compressors, blowers, or pumps. Pump aerators with propeller aspirators, paddlewheel aerators, and vertical aerators are all examples of surface aerators. Numerous Biofloc systems also make use of surface aerators in conjunction with diffused [33]. Considerations like as system depth, system size, and the requirement for effective oxygen transfer and water circulation dictate the aeration system that is chosen. Smaller tanks and basins are more suited for diffused air systems, while grow-out ponds typically use surface aerators [34]. For the Biofloc system to work, it is critical to have adequate aeration and mixing to remove anoxic gases, keep the biofloc particles suspended in the water column, and maintain dissolved oxygen levels [35]. Floating air lines, suspended air stones, and submerged diffusers are all examples of aeration equipment that can be strategically placed and designed to affect Biofloc technology's aeration system efficiency [36].

3.3 Water Quality Management

Biofloc technology's water quality management is essential for long-term aquaculture success. According to Emerenciano et al. [8], biofloc technology (BFT) keeps water quality high by using pathogen competition, in-situ microbial protein production, and feed conversion ratio (FCR) reduction. This technique forms bioflocs, which are protein- and lipid-rich food sources, through interactions between organic matter, physical substrates, and microorganisms [37]. BFT systems minimize water exchange and continuously recycle and reuse nutrients, enabling high fish and prawn production in relatively small areas. There are environmental and financial benefits to using BFT systems because they use 30–50% less water than traditional systems [29]. Inadequate water quality control, a lack of trained personnel, and problems with the system's design are a few of the reasons that might make BFT implementation difficult and expensive [6].

4. BIOFLOC PRODUCTION PROCESS

4.1 Seed Selection and Stocking Density

Biofloc technology (BFT) relies on careful seed selection and stocking densities to maintain water quality and achieve optimal performance in aquaculture systems [15]. On the flip side, water quality and growth performance might be negatively affected by higher stocking densities. The key to a successful BFT implementation is choosing the right species. A study conducted in Bangladesh on the culture of *Heteropneustes fossilis*, for instance, found that lower stocking densities were associated with improved growth performance and profitability [38]. In a similar vein, the butter catfish (*Ompok bimaculatus*) study highlighted how stocking density affects growth, water quality changes, and the efficiency of BFT systems in terms of cost. The optimal stocking density for improving oyster bimaculatus growth, feed utilisation, physiological function, and economic performance is 0.5 g/L. In a biofloc system, the research points the way towards a low-stocking, environmentally and financially viable strategy for butter catfish seed production [39]. Considerations such as seed stocking densities, pond volume, and seed size are crucial to optimising BFT systems for the purpose of increasing productivity while decreasing expenses. In tilapia production, for example, Nugroho et al. [40] discovered that a pond volume of 10 m^3, an initial seed size of 22-27 g, and a stocking density of 75-80 fish/m^3 greatly improved productivity and reduced production costs.

4.2 Feeding Strategies

Biofloc technology's feeding techniques include actions that encourage nutrient utilisation by microorganisms and reduce waste. For optimal growth of the cultivated species and biofloc microbes, select diets that have an adequate amount of protein. According to Khanjani et al. [17], biofloc can meet 20-30% of tilapia's growth needs, which means less supplemental feed is required. The nutritional value of biofloc has been demonstrated to boost feed conversion ratio (FCR) by 42.95% and 44.96%, which may also be applied to prawns. Microalgae added to the biofloc system can boost feed conversion ratio (FCR) and weight gain, which could lead to a decrease in feed expenses [41]. In biofloc systems, species like as tilapia can have an effect on feed utilisation efficiency by adjusting feeding frequency. Mabroke et al. [42] found that optimising stocking density, pond volume, and seed size in biofloc systems can increase productivity and save expenses.

4.3 Monitoring and Management

The surveillance and administration of Biofloc Technology (BFT) encompass various fundamental elements as per the given sources: Regular monitoring of crucial water quality metrics such as ammonia (NH_3), nitrite (NO_2), and nitrate (NO_3) is necessary in BFT systems. Ensuring the ideal water quality is essential for the development and well-being of both the cultivated species and the biofloc microorganisms [8]. It is crucial to monitor the development and properties of the biofloc, including its density, size, and composition, in order to optimise the system. Monitoring biofloc can assure the effective operation of in-situ microorganism production, which is the basis of BFT [43,44]. Deploying automated monitoring and control systems can assist in upholding ideal water quality and biofloc conditions in BFT. Modifying variables such as aeration, feeding, and nutrient inputs according to real-time monitoring data can enhance the efficiency and production of the system [43,44]. BFT (Biofloc Technology) systems can enhance the sustainability of aquaculture techniques by minimising the interchange of water, reusing nutrients, and decreasing reliance on chemical inputs. The creation of microorganisms in the same location in BFT aids in preserving water quality, decreasing feed conversion ratios, and outcompeting diseases, so establishing an ecologically sustainable method [45,8].

5. BENEFITS OF BIOFLOC TECHNOLOGY

5.1 Increased Production Efficiency

Biofloc technology, also referred to as BFT, is an ecologically conscious aquaculture method that enhances the efficient utilisation of resources and facilitates sustainable output. The process entails transforming trash into bioflocs, which act as a natural nourishment for aquatic organisms, hence diminishing the requirement for external resources such as feed and chemicals. Studies have demonstrated that BFT (Biological Farming Technology) can enhance crop yields, economic productivity, and water usage efficiency by as much as 90%. Although there are benefits, there are also obstacles such as the need for a large amount of energy, high initial expenses, and the issue of waste disposal. Nevertheless, by additional investigation and ingenuity, these obstacles can be surmounted, hence enhancing the widespread acceptance and long-term viability of BFT as an aquaculture method. Research has demonstrated that implementing BFT (Biofloc Technology) can enhance profitability by optimising the number of organisms stocked, the rate at which they grow, and by shortening the duration of the culture phase. Aquaculture practitioners can optimise production rates and reduce environmental impact by effectively regulating stocking density. BFT has demonstrated efficacy in enhancing water quality, diminishing wastewater output, and serving as an alternate feed source for aquatic organisms. In summary, BFT provides a more environmentally friendly and productive method of aquaculture production, which can help fulfil the growing demand for aquaculture products while reducing negative environmental effects [6,46,9].

5.2 Water and Resource Conservation

When compared to conventional aquaculture methods, BFT has the potential to cut water usage by as much as 90% all through the production cycle [6]. This is made possible by the system's perpetual water recycling and reuse process. As a natural food source for the aquatic organisms that are cultivated, bioflocs are produced by BFT [47]. Therefore, less nutrient-rich wastewater is discharged and fewer external feed inputs are needed, leading to more efficient use of resources. According to research by Paucar and Sato [48], BFT has the potential to reduce feed consumption per unit of output by improving feed conversion ratios (FCR) to as low as 1.0-1.3. This results in feed resources being used more efficiently. Microbes that can absorb nitrogen from trash and transform it into microbial protein are the backbone of the biofloc system; the cultivated species subsequently feed on this protein [49]. The system's overall efficiency is improved by this closed-loop nutrient recycling. Research is currently underway to find ways to reduce the energy demand of BFT and make it more sustainable. One potential option is solar systems, which could help with aeration and mixing [46,9].

5.3 Disease Management

In Biofloc technology, disease prevention and control focuses on bolstering the immune system of aquatic species to mitigate the occurrence of common diseases and enhance general well-being. Biofloc technology enhances immunological parameters, boosts immune responses, and mitigates the susceptibility to diseases caused by pathogenic microorganisms in comparison to traditional aquaculture systems [50,51]. Biofloc technology improves the growth performance of shrimps and prevents illnesses by encouraging the development of bioflocs and using inexpensive carbon sources [51]. In addition, Biofloc technology utilises antibiotics, probiotics, and prebiotics to provide a sustainable and environmentally friendly method for preventing diseases in aquaculture. This cutting-edge technology not only reduces water consumption but also improves the resistance and well-being of aquatic species, hence promoting the long-term sustainability of the aquaculture business [52].

6. CHALLENGES AND SOLUTIONS

6.1 Environmental Considerations

Biofloc technology aids in the reduction of water use and pollution by efficiently recycling nutrients and minimising the need for water exchange. The biofloc system effectively manages waste and minimises the release of contaminants in comparison to traditional aquaculture methods [53]. Biofloc systems can be combined with other agricultural technologies, such as hydroponics (aquaponics), to establish a self-contained system that enhances resource efficiency and reduces waste [54]. Biofloc technology utilises probiotics and prebiotics to provide a sustainable and environmentally benign method for preventing diseases, hence minimising reliance on toxic chemicals. Biofloc systems necessitate uninterrupted aeration and water circulation to sustain the microbial floc, which might be demanding in terms of energy and expenses, particularly in regions with unpredictable power sources [55]. Inadequate management of anaerobic microbial processes in the biofloc system can lead to the production of extremely toxic chemicals that pose a threat to the cultured aquatic species. Ensuring the appropriate carbon-to-nitrogen ratio and managing water quality factors such as dissolved oxygen, pH, and nitrogenous compounds is essential, but it may provide technical difficulties for certain farmers [17].

6.2 Disease Prevention and Treatment

Biofloc technology focuses on bolstering the immune system of aquatic organisms, including prawns, and ensuring a stable and healthy environment in the aquaculture system to prevent and treat diseases. Biofloc technology might decrease the likelihood of common diseases caused by harmful bacteria in comparison to traditional aquaculture systems by enhancing immunological parameters and increasing immune responses [50,51]. Utilising slow-release carbon sources, probiotics, and maintaining an appropriate carbon-to-nitrogen ratio are essential tactics for boosting immunological activation and preventing illnesses in aquatic species [9]. In addition, biofloc technology stimulates the development of bioflocs, which are clusters of organic material and microorganisms that are rich in protein. These bioflocs serve as a natural source of food for the cultured species, enhancing their growth and overall well-being [51]. Biofloc technology utilises antibiotics, probiotics, and prebiotics to effectively prevent diseases in aquaculture. This approach is sustainable and environmentally friendly, as it reduces reliance on harmful chemicals and ensures the long-term viability of the industry [52,9].

6.3 Operational Challenges

Antimicrobial resistance genes (ARGs) in biofloc technology have been a subject of study due to their implications for aquaculture and environmental safety. Research indicates that biofloc-based aquaculture systems can harbor a variety of ARGs, potentially impacting the aquatic environment. Studies have shown that biofloc systems can contain resistance genes like adeF, OXA-243, and others, which may be transmitted through plasmids and mobile genetic elements. The prevalence of integrons as carriers of ARGs in biofloc environments has also been highlighted. Understanding the presence and transmission of ARGs in biofloc systems is crucial for evaluating the safety and environmental impact of this aquaculture model [56,57,58]. Biofloc contains various bioactive substances that suppress pathogens and improve shrimp immunity. Effective microorganisms in biofloc compete with pathogenic bacteria, limiting their proliferation. Biofloc has been shown to protect against diseases caused by bacteria such as *Vibrio, Aeromonas, Edwardsiella* and *Streptococcus* [59].

6.4 Operational Challenges

The operational challenges in biofloc technology encompass various aspects such as the need for significant energy input, substantial initial and ongoing expenses, effective waste management, scarcity of skilled personnel, inadequate system design, costly aeration requirements, elimination of suspended solids, ensuring appropriate water quality, comprehending operational, aquatic, and microbial dynamics, disease control, and maintaining sufficient alkalinity levels [6,60]. Effective control of the carbon-to-nitrogen ratio is essential for cultivating advantageous microbial communities in the biofloc system [61]. Disproportions in the carbon-to-nitrogen ratio can result in problems such as excessive growth of floc and instability in the system. The requirement for elevated water temperature by the bacteria in biofloc systems can provide a constraint, particularly in regions with unstable power sources [62]. Effective management and monitoring are essential for maintaining the ecological balance of biofloc systems, posing a challenge for certain farmers. Biofloc systems have the potential to host illnesses and parasites, which can be passed to the cultivated aquatic species if not effectively controlled. Biofloc systems are often of a lesser scale compared to traditional aquaculture systems, thereby constraining their capacity for large-scale production [63]. There is a scarcity of evidence regarding the precise function of bioflocs in bolstering the immune system of aquatic creatures. To fully capitalise on the advantages of biofloc technology in sustainable aquaculture, it is imperative to tackle these operational problems by doing additional research and development [12,64-66].

7. CONCLUSION

The utilisation of biofloc technology in aquaculture provides notable benefits for the implementation of sustainable aquaculture techniques. Biofloc technology optimises water conditions, promotes aquaculture yield, and supports the attainment of sustainable development objectives by maximising output while minimising ecological repercussions. This novel method entails the management of water quality, the equilibrium of carbon and nitrogen levels, and the utilisation of protein-rich bioflocs to supply nutrition for aquatic creatures such as tilapia and prawns. Although biofloc technology has difficulties in maintaining the carbon-to-nitrogen ratio and regulating water temperature, its advantages in decreasing water usage, reusing nutrients, and minimising pollution make it a viable method for sustainable aquaculture. In summary, biofloc technology is a vital tool in aquaculture that provides a balance between productivity and environmental responsibility.

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Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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