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## Biofloc Technology for Sustainable Fish and Shrimp Farming

\*Dr. Sruthisree C.

Assistant Professor (Fisheries), University of Agricultural Sciences,  
GKVK, Bangalore, Karnataka, India

\*Corresponding Author's email: [c.shruthi556@gmail.com](mailto:c.shruthi556@gmail.com)

**B**iofloc Technology (BFT) has emerged as a transformative approach in aquaculture, addressing critical challenges related to water quality management, feed efficiency, and environmental sustainability. By promoting the growth of beneficial microbial communities within culture systems, BFT enables in situ nutrient recycling, reduces water exchange requirements, and enhances productivity in fish and shrimp farming. This technology is particularly effective in intensive culture of species such as *Litopenaeus vannamei* and tilapia, where high stocking densities demand efficient waste management strategies. This review explores the principles, mechanisms, advantages, limitations, and future prospects of biofloc technology, highlighting its role in promoting sustainable and environmentally responsible aquaculture.

### Introduction

Global aquaculture has expanded rapidly to meet the rising demand for aquatic protein. However, intensive fish and shrimp farming often generates significant environmental concerns, including nutrient-rich effluents, ammonia accumulation, disease outbreaks, and high water consumption. Traditional systems rely heavily on water exchange to maintain water quality, which increases operational costs and environmental impact. Biofloc Technology (BFT) was developed as a sustainable solution to these challenges. Originally adapted from wastewater treatment principles, BFT promotes the growth of heterotrophic microbial communities that assimilate nitrogenous wastes and convert them into microbial biomass. This microbial biomass, commonly referred to as “biofloc,” serves both as a natural biofilter and as a supplementary feed source for cultured organisms. In recent years, BFT has gained widespread acceptance in shrimp farming, particularly for *Litopenaeus vannamei*, and increasingly in finfish species such as tilapia and carp.

### Principles of Biofloc Technology

The core principle of BFT is the manipulation of the carbon-to-nitrogen (C:N) ratio in the culture system. In conventional aquaculture, nitrogenous wastes primarily originate from uneaten feed and metabolic excretion, especially ammonia. Elevated ammonia levels are toxic to aquatic organisms and must be controlled. In biofloc systems, an external carbon source such as molasses, jaggery, wheat flour, or starch is added to increase the C:N ratio, typically to around 12–20:1. This stimulates the proliferation of heterotrophic bacteria, which assimilate ammonia and convert it into microbial protein. The resulting microbial aggregates consist of bacteria, algae, protozoa, detritus, and organic particles bound together by extracellular polymers. Continuous aeration is essential in BFT systems to maintain floc suspension and ensure adequate dissolved oxygen levels. The microbial community not only controls nitrogen levels but also stabilizes water quality and improves overall system resilience.

## Role in Water Quality Management

Water quality is a critical determinant of aquaculture success. In BFT systems, nitrogenous compounds such as ammonia and nitrite are rapidly assimilated by heterotrophic bacteria, reducing their accumulation. Unlike conventional systems that rely heavily on nitrification by autotrophic bacteria, BFT emphasizes rapid heterotrophic assimilation, which is faster and more efficient under high organic load conditions. The reduction in ammonia toxicity minimizes stress on cultured species and lowers susceptibility to disease. Additionally, minimal water exchange reduces the risk of introducing external pathogens and prevents discharge of nutrient-rich effluents into the environment. By maintaining stable water parameters, biofloc systems create a more controlled and biosecure culture environment.

## Nutritional Benefits and Feed Efficiency

One of the most significant advantages of BFT is its contribution to improved feed utilization. Bioflocs contain microbial protein, lipids, vitamins, and minerals that serve as a supplementary natural food source. Species such as shrimp and tilapia actively consume bioflocs, thereby improving growth performance and feed conversion ratio (FCR). Studies have demonstrated that biofloc systems can reduce feed protein requirements by partially replacing dietary protein with microbial biomass. This is particularly important in shrimp farming, where feed accounts for the majority of production costs. Improved FCR not only enhances profitability but also reduces nutrient discharge into the environment. The presence of beneficial microbes also enhances digestive enzyme activity and gut health, further contributing to efficient nutrient assimilation.

## Disease Control and Immune Enhancement

Disease outbreaks remain a major constraint in intensive aquaculture. Biofloc systems promote a stable and competitive microbial environment that suppresses opportunistic pathogens. Beneficial bacteria within the floc community compete with harmful microbes for nutrients and attachment sites. Furthermore, biofloc consumption has been associated with enhanced immune responses in shrimp and fish. Increased hemocyte activity, improved antioxidant status, and higher resistance to pathogens such as *Vibrio* species have been reported in shrimp cultured under BFT conditions. The reduced need for water exchange also minimizes the introduction of disease-causing organisms, contributing to improved biosecurity.

## Sustainability and Environmental Impact

Sustainability is a growing priority in global aquaculture. Biofloc technology significantly reduces water usage, making it particularly suitable for regions facing water scarcity. Because water exchange is minimal, environmental discharge is drastically reduced, lowering the ecological footprint of aquaculture operations. Nutrient recycling within the system enhances resource efficiency. Instead of being lost as waste, nitrogen is converted into usable microbial biomass. This circular nutrient utilization aligns with the principles of sustainable and climate-resilient aquaculture. Moreover, reduced reliance on antibiotics and chemical treatments further supports environmentally responsible farming practices.

## Challenges and Limitations

Despite its advantages, BFT requires careful management and technical expertise. Continuous aeration demands substantial energy input, increasing electricity costs. Poor aeration may lead to floc settling and oxygen depletion, which can be detrimental to cultured organisms. Maintaining optimal C:N ratio and monitoring total suspended solids (TSS) are critical for system stability. Excessive floc accumulation can impair water quality and cause gill irritation in fish and shrimp. Initial setup costs and the need for technical training may limit adoption among small-scale farmers. However, long-term benefits often outweigh initial investments when properly managed.

## Future Prospects

The future of biofloc technology lies in integration with other sustainable aquaculture approaches such as recirculating aquaculture systems (RAS) and aquaponics. Advances in microbial ecology and metagenomics are providing deeper insights into biofloc community dynamics, enabling optimization of system performance. Automation of aeration and real-time water quality monitoring systems will enhance efficiency and reduce labor requirements. Additionally, research into species-specific biofloc management strategies will expand the applicability of BFT across diverse aquaculture species.

## Conclusion

Biofloc Technology represents a sustainable and innovative solution for modern fish and shrimp farming. By promoting nutrient recycling, improving feed efficiency, enhancing disease resistance, and reducing environmental impact, BFT addresses many of the challenges associated with intensive aquaculture. Although effective management and energy considerations are essential, the long-term ecological and economic benefits make biofloc technology a cornerstone of sustainable aquaculture development. Continued research and technological refinement will further strengthen its role in meeting global seafood demand responsibly.

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