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# Beneficial Effects of Biofloc Technology in Aquaculture Systems

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## Abstract

The rapid expansion of the aquaculture sector causes an environmental impact and it mainly depends on the fishmeal diet these problems are reduced through the implementation of biofloc technology. It is containing more nutritional composition as well as several bioactive compounds such as bromophenols, carotenoids, chlorophylls, poly-beta-hydroxybutyrate and phytosterols they act as natural probiotic and immunostimulant. These beneficial compounds improve the growth, survival, defence mechanisms and also considered as novel technology for aquatic animal health management in aquaculture by stimulating nonspecific defense mechanism of cultured animals. Moreover, biofloc technology served as a bioremediation tool to provide a sustainable and eco-friendly environment, biosecurity, and low risk of pathogen and disease introduction which gives high production yield to reduce the poverty alleviation. This article highlights the beneficial effects of biofloc technology in aquaculture production and their application in the various purposes of culture systems.

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## Introduction

The rapid growth and intensification of aquaculture produce a tremendous amount of carbon-based pollutants causing toxic effects and environmental risks. The goals of the aquaculture system are successfully achieved through the implementation of biofloc technology. In recent years, recirculating systems have been developed which create a way to achieve sustainable aquaculture development and contain suitable methods to control the production of aquaculture wastewater. In this culture method 10% of the total volume of water should be replaced daily. Farmers in developing countries do not adopt the recirculating system due to high operating and maintenance costs. Therefore, require a low operating cost, sustainable and eco-friendly technology that is acceptable to farmers and provides high production and yield without damaging the surrounding environments.

The basic principle of the activated suspension technique (AST), lately mentioned to as biofloc technology (BFT). Biofloc technology is a technique for improving the water quality in aquaculture by manipulating carbon and nitrogen in the system. Also improving feed conversion ratio (FCR), application of low-protein diets, reducing costs of production and replacing conventional high-cost feeds along with alternative protein sources. Hargreaves (2013) defined the biofloc as “a mixture of algae, bacteria, protozoans and other kinds of particulate organic matter such as feces and uneaten feed in addition to some of zooplankton and nematodes, formed together to be an integrated and interdependent ecosystem”. The working principle of biofloc technology

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is mainly based on the flocculation or co-culture of heterotrophic bacteria and algae associated with the system. The major advantages of biofloc technology in aquaculture as an environmental and sustainable technology that means low feed cost and zero water exchange, prevention of entry of pathogens and diseases, maintaining good biosecurity conditions, increased growth and survival rate, and also given high production rate. The implementation of biofloc technology in aquaculture provides a beneficial effects on the culture environment as well as on cultured animals (Table 1).

Table 1: Recent application of biofloc technology (BFT) in aquaculture (Jamal *et al*., 2020)

| Cultured species | Application | Effect on culture water | Effects on cultured animals |
|---|---|---|---|
| Banana shrimp (*Fenneropenaeus merguiensis*) | Nursery based BFT | Improved water quality; reduced the total ammonia nitrogen and nitrite | Improved growth performance and survival rate |
| Seahorse (*Hippocampus erectus*) juvenile | Different carbon sources and carbon–nitrogen based BFT | Reduced ammonia and nitrite; promote the bacterial proliferation and community diversity | Improved survival of the juveniles; Increased the intestinal microflora, digestion, and immunity |
| *Pangasianodon hypophthalmus* | Biofloc system with photoperiod manipulation | Improved water quality | Improved health status and no negative effect on the organs |
| Common carp (*Cyprinus carpio* L.) juveniles | Wheat and rice bran fermented with probiotic based BFT | Improved water quality through reduction of total ammonia nitrogen | Enhanced the growth performance and health status; improved intestine mucosal layer |
| Shrimp (*Litopenaeus vannamei*) | Bio-augmented with probiotic bacteria *Bacillus tequilensis* AP BFT | Increased heterotrophic bacterial community; abundance of enzyme-producing bacterial population | Upregulated immune-related genes; induced the essential protein and reduced contracting diseases |
| Shrimp (*Litopenaeus vannamei*) | Nursery - bioaugmentation microalgae (*Platymonas* sp.) based BFT | Promoted nitrification, denitrification, and improved alpha diversity of bacterial communities | Increased survival rate, specific growth rate and weight gains; improved antioxidant enzymes |
| Nile tilapia, (*Oreochromis niloticus*) fry | BFT | Reduced ammonia and nitrite | Increased growth rate and protein utilization efficiency; improved FCR |
| *Litopenaeus vannamei* | Nursery - yeast based BFT | Reduced total suspended solids | Increased the growth and survival |
| Red hybrid tilapia (*Oreochromis* spp.) fingerlings | Probiotic based BFT | Reduced the nitrogen concentration | Increased survival rate, specific growth and feed conversion ratio |
| Nile tilapia (*Oreochromis niloticus*) fry | BFT | Improved water quality parameters (reduced TAN, $NO_2$, $NO_3$, settled solids and total suspended solids) | Improved the growth rate, weight gain, specific growth rate and FCR |
| Shrimp (*Litopenaeus vannamei*) | Biofloc-based super-intensive tank system | Limited water exchange due to low concentrations of TAN and $NO^-_2$-N at late stage; diversed group of bacterial communities | Better growth performance in outdoor conditions than in indoors |

Table 1: Continue...

| Cultured species | Application | Effect on culture water | Effects on cultured animals |
|---|---|---|---|
| Nile tilapia (*Oreochromis niloticus*) | Symbiotics -prebiotics and probiotics based BFT | Reduced concentration of nitrite | Enhanced the specific growth rate, final weight, weight gain and improved the hematological parameters |
| Shrimp (*Litopenaeus vannamei*) | Wheat flour based - zero-water exchange-BFT | Effectively recovered and maintained the water quality without sodium bicarbonate; higher bacterial diversity | Affected growth performance |
| Juvenile of *Cachama blanca* (*Piaractus brachypomus*) | BFT | Maintenance of the all parameters of water quality in the acceptable range except toxic nitrogen compounds ($NH_4^-$ and $NO_2^-$) | Enhanced growth performance |
| *Litopenaeus vannamei* | Horizontal and vertical substrate based BFT | Maintained optimal levels of water quality parameters | Improved the final weight, survival, final biomass, yields and FCR |
| Amur minnow (*Rhynchocypris lagowski*) | BFT with differential protein | No significant change in water quality parameters | Enhanced the growth rate, digestive enzymes activity, immune response, antioxidant statue and higher expression of antioxidant-related genes |
| Prawn (*Macrobrachium rosenbergii*) post-larvae | Synbiotic system based BFT | Maintained the acceptable level of water quality | Improved growth performance |
| Mullet (*Mugil liza*) and shrimp (*Litopenaeus vannamei*) | BFT in integrated culture system | Improved bacterial nitrification; reduced total suspended solids (TSS) concentration | Enhanced growth rate of mullet and reduced the shrimp growth |
| Nile tilapia (*Oreochromis niloticus*) | Biochar-based BFT | Reduced total suspended solids; Improved water quality through active heterotrophic bacterial assimilation and nitrification; enhanced levels of $NO^-_3$ and total nitrogen | No notable negative effects of biochar on growth and physiological performance |
| Indian major carps, *e.g.*, rohu (*Labeo rohita*), catla (*Catla catla*), and mrigal (*Cirrihinus mrigala*) | BFT for polyculture | Maintenance of $NH_4$-N, $NO_2$-N and $NO_3$-N in the acceptable range of water quality | Reasonable growth performance (higher rate of specific growth) |
| Nile tilapia (*Oreochromis niloticus*) | Jaggery-based biofloc technology | Reduced the total ammonia nitrogen (TAN), nitrite and ammonia | Improved the growth and survival; increased the serum antioxidants, lysozyme, protease, antiprotease and bactericidal activity against to *A. hydrophila* infection |

## Biofloc Technology

Biofloc technology is a technique of improving the water quality through the addition of extra carbon sources to produce a high amount of microbial bacterial floc in the aquaculture systems due to a high level of aeration. In this system manipulation of carbon and nitrogen ratio at 10:1 is important that maintained by the addition of carbon sources of organic materials such as molasses, wheat flour, starch, or reducing the protein level of the feed will increase the activity of heterotrophic bacteria.

Heterotrophic bacteria growth is enhanced by the addition of an extra carbon source which is the energy source for the conversion of nitrogenous waste into the beneficial microbial protein as well as the production of new bacterial biomass in the cultured system. This technology rapidly reduces the ammonium concentration in the culture system than the nitrification process and encourages the nitrogen uptake through bacterial biomass. The working method of this technology mainly based on the basic principle of flocculation as co-culture of heterotrophic bacteria and algae within the culture system. In this system also known as the green approach in aquaculture called various names such as zero exchange autotrophic-heterotrophic system, active sludge or suspended bacterial based system, single-cell protein production system, microbial floc system, *etc*.

## Biofloc as an Aquaculture Feed

Bioflocs contain various nutritional components including protein, lipid, carbohydrate, and ash content used as feed for the growth of fish and shrimp in aquaculture while much research is needed on the feed composition of aquaculture for amino acid and fatty acid. Production of new biomass in BFT is applied as alternative food source to cultured animals. In some research findings they reported biofloc as a dietary supplement at a 4% level in shrimp feed for enhancing growth and digestive enzyme activities in tiger shrimp juvenile; waste biofloc has the potential to be used as a cost-effective feed for rearing shrimp PLs; positive relationship between the growth parameters and the protein content of the feeds in this system, and confirms the benefit of natural productivity for production of *L. vannamei* and bioflocs can improve growth performance and feed utilization of the cultured shrimp, probably through providing a supplemental food source and enhancing feed digestion and utilization.

The biofloc system comprises the heterotrophic food web which shows the cultured fish species may feed directly or indirectly on primary producers. Also, this system contains the organic waste they transformed into a food source by bacteria and which acts as a food source for cultured fishes. The biofloc system has the potential to reduce the cost of production due to reducing the feed cost and also provide good environmental conditions to the culture system through reduce the accumulation of uneaten feed and nitrogenous waste in the culture pond.

## Nutritional Composition of Biofloc

Biofloc contains many nutritional compositions which provide opportunities to economically produce a healthy, high-quality product. However, biofloc have a dynamic nutritional value and used as complete source of aquatic food also provide the many bioactive compounds. The nutritional value of biofloc determined by several factors such as animal's food preferences, their capacity to swallow and digest microbial protein and the density of the flocs in the water. The heterotrophic bacteria produce the single-cell protein during uptake of inorganic N can be used as a food source for cultured aquatic animals such as carps, tilapia and shrimp.

The quality of biofloc comprises 38% protein, 3% lipid, 6% fiber, 12% ash, and 19 kJ $g^{-1}$ energy (on dry matter basis). Many researchers have been reported different nutritional composition in biofloc system which is mainly depends on usage of carbon source. The feasibility of the bioflocs as feed in aquaculture mainly depends on the important parameters of high protein, polyunsaturated fatty acid (PUFA) and lipid content. Not only the nutritional composition of biofloc is important and other internal compounds also have beneficial to cultured aquatic organisms.

## Biofloc as a Biocontrol Measure (Bioremediation)

Biofloc considered as novel strategy disease management in aquaculture with perspective of antibiotic, probiotic and prebiotic application. Biofloc interferes with the quorum sensing mechanisms as well as bacterial cell-to-cell communication with small signal molecules which has been proposed as a novel approach to the control of bacterial diseases in aquaculture. In this culture system pH level will be decreased due to the transformation of sugars into lactic acid through *Lactobacillus* sp. and also avoids the proliferation of pathogens within the culture system.

The species composition of the *Vibrio* community in the culture system is altered by probiotics. In biofloc technology, probiotic is known to produce the communication molecules which can be disturbed the communication between vibrios and thus inhibit their proliferation. In previous reports, biofloc contains intracellular biodegradable polymer poly-β-hydroxybutyrate (PHB) and PHB accumulating bacteria which protect the various cultured aquatic animals from bacterial diseases. PHB act as a prebiotic advantage for aquaculture. Presence of PHB in culture system is controlled by addition carbon source it helps to enhance the particular group of polyhydroxyalkanoate (PHA) accumulating bacteria such as *Alcaligenes eutrophus*, *Azotobacter vinelandii*, *Pseudomonas oleovorans* and others that produce the PHA granules. This can be reducing the pH level and inhibit the proliferation of pathogenic bacteria in culture system.

## Immuno-Physiological Activity through Biofloc

The immune responses are activated by physical damage (injury) or by pathogenic invasion which induces the phagocytosis and inflammatory processes assisted by

non-specific immune cells such as macrophages, neutrophils, and non-specific cytotoxic cells. When bacterial biomass increases in the adjacent water which they stimulate the production of glycoproteins from fish skin mucus. When fish are exposed to infections, they release a variety of humoral factors such as cytokines, anti-proteases, peroxidases, lysozymes, *etc*.

Recently, researchers assumed the potential of immunostimulatory features of the biofloc has been important to the development of the immunity and antioxidant status of shrimps and fishes that provide the resistance to numerous infections or pathogenic invasions. Biofloc contains heterotrophic microbial biomass that inhibits the growth of pathogenic bacteria in the culture system. According to the study, floc contains carotenoids which have been providing vital nutritional and also bioactive compounds that stimulate the immune system of cultured animals.

The many existing immunostimulants as natural or synthetic compounds are derived from various sources such as bacteria, bacterial products, plants, and animals. Since biofloc system have the bacterial environment which enhances the beneficial effect on the health of culture animals because it contains some immunostimulatory compounds. Several studies reported that the microorganisms and their cell components are used as probiotics or immunostimulants they improve disease resistance in shrimp due to the activity of nonspecific defense mechanisms and antioxidant activity. The shrimp body continuously intakes some beneficial microorganisms as essential microbial components from biofloc culture system that enhance the immune system of the cultured animals. Therefore, development welfare of fish in aquaculture is required the further research work for actual mechanisms of humoral innate or cellular immune response which determine the protective biofloc life of bacteria.

## Conclusion

Biofloc technology is an environmentally friendly approach to achieving the goal of sustainable aquaculture without damaging the surrounding environment. The importance of biofloc system is to act as a food source for cultured animals it decreases feed costs by reducing the FCR. Biofloc technology maintains good environmental conditions in the culture pond by preventing the excess accumulation of nitrogenous waste, feces from culture animals, and uneaten food. Biofloc technology improves the sustainability, biosecurity and development of high production yield through zero water exchange for entire crop cycle. Another factor biofloc have bioactive compounds with many nutritional factors that improve the health status of cultured animals. This technology has microbial communities served as probiotic and immunostimulants that involved in many immunological functions in cultured animals which includes bioremediation, competitive exclusion, immunomodulation, provision of additional nutrients and interruption of quorum sensing. The necessities for a sustainable and eco-friendly approach to aquaculture development can be attained through the application of biofloc technology.

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