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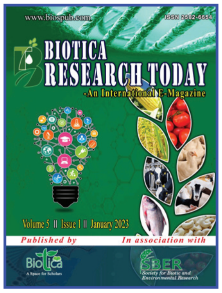

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Biofloc Technology: Innovative Approach towards Sustainable Aquaculture

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Abstract

Biofloc technology (BFT) is an eco-friendly aquaculture approach that allows continuous recycling and reuse of nutrients in the system and reduces water exchange while providing added value resulting from microbial metabolism. The BFT system is a cutting-edge method of fish culture that is mostly used for shrimp and tilapia in India. Over time, as more people became aware of the technique, many other fish species were successfully produced in the system. BFT is one of the best system in today scenario as it help in reducing high operational cost, cost of land use, high cost of feed and discharge and disposal of waste sludge, thus minimizing water pollution. It also reduces the spread of pathogens and also improves fish health. In this article, we have given an overview of Biofloc system, fish species cultured in the system and a pilot study is also discussed.

Introduction

Biofloc technology (BFT) is an environmental friendly aquaculture approach based on the maintenance of high levels of microbial floc in production system using continuous aeration. The microbial floc uses are combination of algae, bacteria or protozoa that are held together in a matrix along with particulate organic matter for the purpose of improving water quality, diseases prevention and waste treatment in intensive aquaculture systems. BFT focuses on more efficient use of nutrient input with limited or zero water exchange system and addition of carbohydrates to allow aerobic decomposition of the organic material (Avnimelech, 2009). The bioflocs are rich protein-lipid natural source of food which are available 24 hours due to complex interaction between large variety of microorganism, organic matter and physical substrate, playing important roles in recycling nutrients, controlling water quality and also acts as protein source for fishes and shrimps (Avnimelech, 1999).

Biofloc Technology?

BFT is an innovative aquaculture technique, usually run in a closed setup with minimum water and nutrient discharge and no complex filters. In this process, conversion of nitrogen into microbial biomass occurs by manipulating the carbon: nitrogen (C:N) ratio of water and providing sufficient aeration. Carbohydrates addition to the system stimulates heterotrophic bacterial growth and production of microbial proteins through nitrogen uptake. Continuously water movement in the entirely water column is required to induce the macro-aggregate (biofloc) formation. Nutrients in water will naturally aid in the establishment and stabilisation of a heterotrophic microbial population. Maintaining the C/N ratio in the aquaculture system, through the external addition of carbon source or elevated carbon level in the feed, water quality can be improved along with the production of high-quality single-cell microbial protein (Crab *et al.*, 2012). Since nutrients can be continuously recycled and reused in the culture medium, with minimum or zero-water exchange, BFT is often considered as the 'new blue revolution'. Additionally, high fish/ shrimp production in small areas is the foundation of this system's sustainable approach. The consumption of biofloc by fish/ shrimp has demonstrated numerous benefits such as improvement of growth rate, decrease of FCR, and associated costs in feed.

Working Principle of BFT

The basic principle of BFT is mainly based on recycling of waste nutrients, in particular nitrogen, into microbial biomass that can be used *in situ* by cultured animals or be harvested and processed into feed ingredients. It depends on the maintenance of carbon/ nitrogen supplementation which stimulates the growth of heterotrophic microbiota by steering the C/N ratio in the water by the addition of an external carbon source in the water or through modification of carbohydrate content in the feed. Supplemented carbon will help to hold the excreted ammonia from the animals. Immobilization of toxic nitrogen species occurs much more rapidly in bioflocs because the growth rate and microbial biomass production per unit substrate of heterotrophs are 10 times higher than those of autotrophic nitrifying bacteria (Crab *et al.*, 2007; Avnimelech, 2009). Therefore ammonium/ ammonia can be maintained at a low and non-toxic concentration so that water replacement is no longer required.

Role of Microorganism in BFT

In BFT, microorganisms present a key role in nutrition of cultured animal and managed to control ammonia released by the cultivated organisms. The macroaggregates (biofloc) is a rich protein lipid natural source available "in situ" 24 hours per day. In the water column occurs a complex interaction between organic matter, physical substrate and large range of microorganisms such as phytoplankton, free and attached bacteria, aggregates of particulate organic matter and grazers, such as rotifers, ciliates and flagellates protozoa and copepods. This natural productivity plays an important role recycling nutrients and maintaining the water quality. Also, consumption of macroaggregates can increase nitrogen retention from added feed by 7-13%. Heterotrophic bacteria identified from Pseudomonas and Aeromonas family consumed the organic matter loaded at the bottom of culture tank and converted items through chemical process as useful protein food to be consumed back by the aquatic organism. Usually in BFT, heterotrophic bacteria are more dominant than nitrifying bacteria because of their higher growth rate and microbial biomass yield per substrate, thus making many fold increase of heterotrophic bacteria. *Bacillus* sp. is also found to improve water quality, performance and immunological parameters when added to the water and diet.

Regarding to maintenance of water quality, control of bacterial community over autotrophic microorganisms is achieved using a high carbon to nitrogen ratio (C: N), which nitrogenous by-products can be easily taken up by heterotrophic bacteria. By addition of cheap carbohydrate sources such as molasses or tapioca usually in ration around C:N 12-15:1 in the water column, biofloc will convert the toxic nutrients in the water to beneficial food sources for fish consumption. High carbon to nitrogen ratio is required to guarantee optimum heterotrophic bacteria growth, using this energy for maintenance (respiration, feeding, movement, digestion, *etc*.), but also for growth and to produce new cells. Bacteria and other microorganisms act as very efficient "biochemical systems" to degrade and metabolize organic residues. One of the techniques used to quantify bioflocs is to measure the total suspended solids (TSS) in the water. In BFT systems, reduced water exchange, high organic matter input, and high growth rates of heterotrophic bacteria contribute to an increase in TSS. The density of suspended solids after oxygen is the second most important limiting factor to increased productivity. Therefore, some solids removal is essential to keeping the system stable and healthy for the cultivated organisms.

Preparation of Biofloc

For biofloc technology as a start-up, certain period is required to obtain a well-functioning system with respect to controlling water quality and that depend on the nitrogen and organic load of the culture water. To stimulate the formation of biofloc in tanks or pond, a calculated amount of pond bottom clay should be added to the water in the system. To accelerate the start-up, preparation of inoculum can be carried out with 20 g of pond bottom soil, 10 mg ammonium sulphate $(NH)_4SO_4$ and 200 mg of carbon sources in 1 l of water or inoculation with water from existing biofloc ponds. The carbon source serves as a substrate for operating BFT systems and production of microbial protein cells. Carbon sources used in BFT are often by-products from the food and/or animal food industry and are preferably locally available. Cheap sources of carbohydrates such as molasses, glycerol and plant meals (*i.e.*, corn, wheat, rice, tapioca, *etc*.) will be applied before post-larvae stocking and during grow-out phase, aiming to maintain a high C:N ratio (~15-20:1) and to control N compounds peaks. A mixture of plant meals can be pelleted and introduced into the system, alternatively, a low protein diet with high C:N ratio can be followed (Crab *et al*., 2012).

Application of BFT in Aquaculture System

For aquaculture in BFT system, fish species that can derive nutritional advantage directly by direct consumption of floc are best suitable for BFT culture. Fish species such as tilapia, carps, air-breathing fishes, prawns and shrimps were cultured in the system. In a successful BFT system for fish culture, culture pond was prepared with 30% of water increasing upto 100% in a week, manured by applying urea (400 g), molasses (1.5 l) and diammonium phosphate (200 g). A high stocking density for fish was kept at 20-30 kg m^{-3} with high feeding intensity (ca 500 g feed m^{-3} day^{-1}), high floc volume (20-50 ml l^{-1}), high and effective aeration 10-20 hp/ 1000 m^2, very high natural feed storage and high microbial activity. Draining of excessive sludge is required daily or twice daily. Protein feed of 25-35% is required in a biofloc culture system depending on the species cultured may increase upto 50% at the rate of 5% of the body weight (Schneider *et al.*, 2006; Crab *et al.*, 2012). During the lockdown period, a fisheries graduate Bijit Bania of Udalguri district, Assam started BFT system for fish culture at his house backyard (Figure 1). He used locally available materials to make the system. Jaggery, raw salt and probiotics were used to maintain the system. In the BFT system, he cultured *Anabas testudineus*, *Heteropneustes fossilis* and *Clarias batrachus* (Figure 2). The harvested fish from the BFT system was used for home and local consumption during the lockdown period.

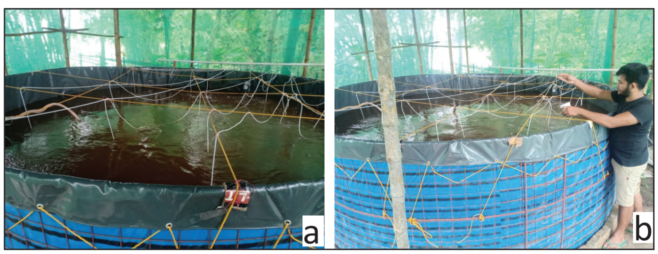

Figure 1: (a) BFT system for fish culture and (b) Monitoring BFT system

Nursery and Grow Out System

Nursery phase is defined as an intermediate step between hatchery-reared early post-larvae and grow-out phase. Such phase presents several benefits such as optimization of farm land, increase in survival and enhanced growth performance in grow-out ponds, while also contributing to more favourable water quality conditions. BFT has been applied successfully in nursery phase in different shrimp and fish species. The primary advantage observed is related to a better nutrition by continuous consumption of biofloc, which might positively influence grow-out performance. In addition, optimization of farm facilities provided by the high stocking densities in BFT nursery phase seems to be an important advantage to achieve profitability in small farms, mainly in cold regions or when farmers are operating indoor facilities. It was observed that presence of biofloc resulted in increases of 50% in weight and almost 80% in final biomass in early post larval stage of shrimp and survival rates ranges from 97% and 100%, respectively. Floc biomass might provide a complete source of cellular nutrition as well as various bioactive compounds even at high density.For fish and other species, intensive BFT *Oreochromis niloticus* tilapia culture could produce an equivalent of 155 ton $ha^{-1}crop^{-1}$. Feed utilization by tilapia is higher in BFT with a ration 20% less than conventional water exchange system. Besides high yields, decrease of FCR and decreased of protein content in diets have also been observed. It was observed that using glucose or a combination of glycerol plus Bacillus as a carbon source in bioreactors led to higher biofloc protein content, higher n6 fatty acids, which resulted in improved survival rates.

Breeding

BFT could enhance spawning performance as compared to the conventional pond and tank-reared system, respectively (*i.e.*, high number of eggs per spawn and high spawning activity). Such superior performance might be caused by better control of water quality parameters and continuous availability of food (biofloc) in a form of fatty acids protected against oxidation, vitamins, phospholipids and highly diverse "native protein". These nutrients are required to early gonad formation in young breeders and subsequent ovary development.

Figure 2: (a) Koi fish and (b) Singhi fish from BFT system

Advantages of Biofloc Technology

- It is robust, easy to operate and economically feasible.
- BFT has the capacity to recycle waste nutrients through microbial protein into fish or shrimp.
- It provides more economical alternative and sustainable technique in terms of minimal water exchange and reduced feed input making it a low-cost sustainable technology for sustainable future aquaculture development.
- Eco-friendly farming practices, with limited water exchange providing sustainable alternative for intensive farming and biosecurity.
- Zero water exchange in BFT system has advantages of

maintaining temperature and heat fluctuations.

• It supports nitrogen removal even when organic matter and biochemical oxygen demand of the system is high.

• Less risk of pathogen and diseases.

• More biosecurity, increased growth and survival, hence increasing crop yield.

Future Perspectives

Water scarcity, rising protein food demand, and land use conflict related to the spread of aquaculture techniques have all become a major problem at global level. Intensive aquaculture is one of the main methods to meet the rising demand. Aquatic environments will be harmed by the large amount of effluents produced by intensifying aquaculture operations. Moreover, the intensification will lead to heavy dependence on fish meal which is a scarce commodity, disease outbreaks in the cultured organisms, environmental degradation, and socioeconomic conflicts. In an attempt to minimize the impact of the environmental, health, and economic problems associated with aquaculture, Biofloc technology has become increasingly popular as a sustainable alternative for intensification and has been successfully implemented, especially for shrimp aquaculture farming and has been conducted in several fish species due to environmental, economical and marketing advantages over a conventional culture system.

Conclusion

Even though commercial applications for biofloc systems have been in place since the early 2000s and research into them has been ongoing since the early 1990s, fundamental aspects of how these systems work are still not well understood. This may be due to the fact that only tilapia and shrimp have been widely cultured in biofloc systems, and that only those types of production systems have been tested. In order to use the advantages of biofloc technology in every aquaculture system, adequate guidelines and design criteria for standard biofloc culture systems should be devised for commercially relevant fish species.

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