Biofloc Technology in Aquaculture

Introduction

With almost seven billion people on earth, the demand for aquatic food carries on to increase and hence, expansion and intensification of aquaculture production are highly required. The prime goal of aquaculture expansion must be to produce more aquaculture products without significantly increasing the usage of the basic natural resources of water and land. The second goal is to develop sustainable aquaculture systems that will not damage the environment. The third goal is to build up systems providing an equitable cost/benefit ratio to support economic and social sustainability. All these three prerequisites for sustainable aquaculture developmentcan be met by biofloc technology.

Biofloc systems were developed to improve environmental control over production. In places where water is scarce or land is expensive, more intensive forms of aquaculture must be practiced for cost-effective production. There are strong economic incentives for an aquaculture business to be more efficient with production inputs, especially the most costly (feed) and most limiting (water or land). High-density rearing of fish typically requires some waste treatment infrastructure. At its core, biofloc is a waste treatment system. Biofloc systems were also developed to prevent the introduction of disease to a farm from incoming water. In the past, standard operation of shrimp ponds included water exchange (typically 10 percent per day) as a method to control water quality. In estuarine areas with many shrimp farms practicing water exchange, disease would spread among farms. Reducing water exchange is an obvious strategy for improving farm biosecurity. Shrimp farming began moving toward more closed and intensive production where waste treatment is more internalized. Biofloc systems use a counter-intuitive approach— allow or encourage solids and the associated microbial community to accumulate in water. As long as there is sufficient mixing and aeration to maintain an active floc in suspension, water quality can be controlled. Managing biofloc systems is not as straightforward as that, however, and some degree of technical sophistication is required for the system to be fully functional and most productive.

Need for Biofloc System

Biofloc system was developed to improve the environmental control over the aquatic animal production. In aquaculture, the strong influential factors are the feed cost (accounting to 60% of the total production cost) and most limiting factor is the water/land availability. High stocking density and rearing of aquatic animals requires wastewater treatment. Biofloc system is a wastewater treatment which has gained vital importance as an approach in aquaculture.

The principle of this technique is the generation of nitrogen cycle by maintaining higher C: N ratio through stimulating heterotrophic microbial growth, which assimilates the nitrogenous waste that can be exploited by the cultured spices as a feed. The biofloc technology is not only effective in treating the waste but also grants nutrition to the aquatic animal.

The higher C:N is maintained through the addition of carbohydrate source (molasses) and the water quality is improved through the production of high quality single cell microbial protein. In such condition, dense microorganisms develop and function both as bioreactor controlling water quality and protein food source. Immobilization of toxic nitrogen species occurs more rapidly in bioflocs because the growth rate and microbial production per unit substrate of heterotrophs are ten-times greater than that of the autotrophic nitrifying bacteria. This technology is based on the principle of flocculation within the system.

The biofloc technology has been implemented in shrimp farming due to its bottom dwelling habit and resistance to environmental changes. Studies have been conducted to assess the larval growth and reproductive performance of shrimps and Nile tilapia. An improved breeding performance was observed in shrimp reared in the biofloc system when compared to that of normal culture practices. Similarly improved larval growth performance was also noticed.4

Composition and nutritional value of bioflocs

Bioflocs are aggregates (flocs) of algae, bacteria, protozoans, and other kinds of particulate organic matter such as feces and uneaten feed. Each floc is held together in a loose matrix

of mucus that is secreted by bacteria, bound by filamentous microorganisms, or held by electrostatic attraction. The biofloc community also includes animals that are grazers of flocs, such as some zooplankton and nematodes. Large bioflocs can be seen with the naked eye, but most are microscopic. Flocs in a typical greenwater biofloc system are rather large, around 50 to 200 microns, and will settle easily in calm water.

The nutritional quality of biofloc to cultured animals is good but rather variable. The dry-weight protein content of biofloc ranges from 25 to 50 percent, with most estimates between 30 and 45 percent. Fat content ranges from 0.5 to 15 percent, with most estimates between 1 and 5 percent. There are conflicting reports about the adequacy of bioflocs to provide the often limiting amino acids methionine and lysine. Bioflocs are good sources of vitamins and minerals, especially phosphorus. Bioflocs may also have probiotic effects. Dried bioflocs have been proposed as an ingredient to replace fishmeal or soybean meal in aquafeeds. The nutritional quality of dried bioflocs is good, and trials with shrimp fed diets containing up to 30 percent dried bioflocs show promise. Nonetheless, it is unlikely that dried bioflocs could replace animal or plant protein sources used in commercial-scale aquafeed manufacturing because only limited quantities are available. Furthermore, the cost-effectiveness of producing and drying biofloc solids at a commercial scale is questionable.

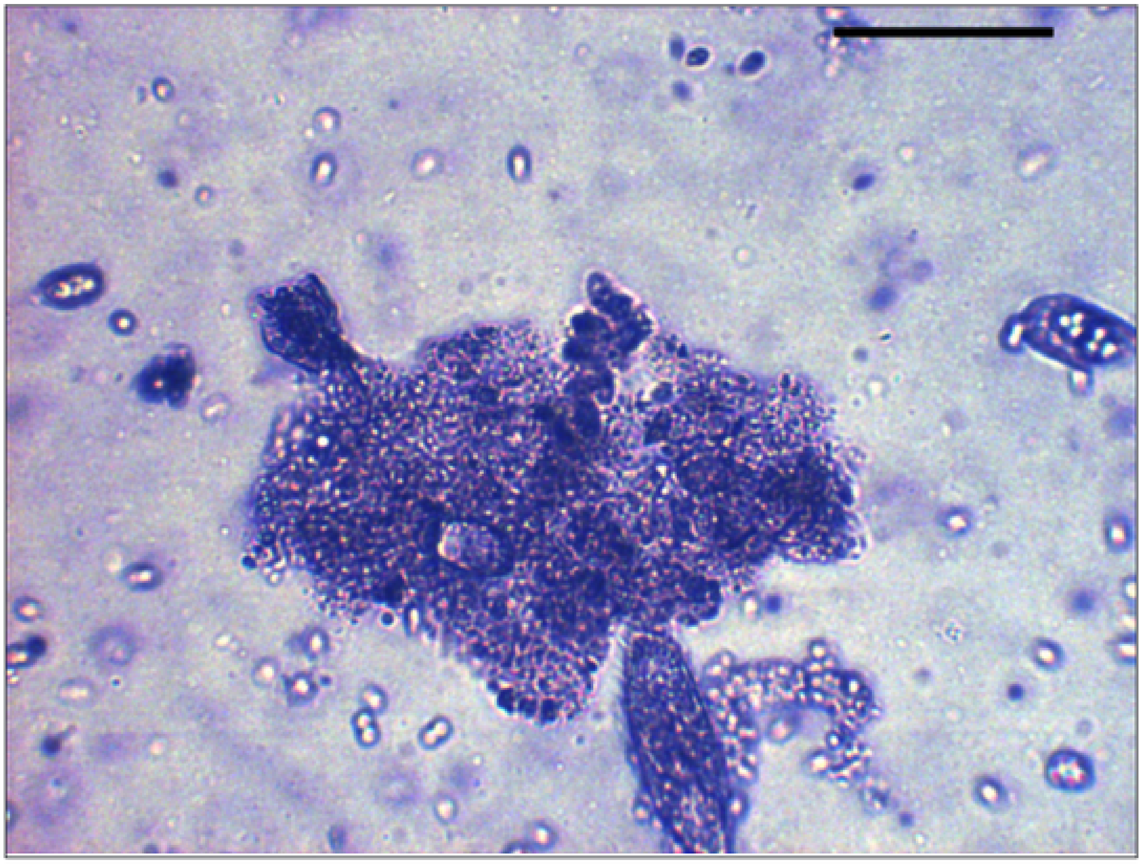

Figure 1. An individual biofloc from an indoor system. The scale bar is 100 microns.

Working of Biofloc Systems

Bioflocs provide two critical services—treating wastes from feeding and providing nutrition from floc consumption. Biofloc systems can operate with low water exchange rates (0.5 to 1 percent per day). This long water residence time allows the development of a dense and active biofloc community to enhance the treatment of waste organic matter and nutrients. In biofloc

Figure 3. Imhoff cones to measure biofloc as the concentration of solids that settle after 10 to 20 minutes. The desired range for operation of biofloc systems is a settleable solids concentration of 10 to 15 mL/L for shrimp and 25 to 50 mL/L for tilapia.

systems, using water exchange to manage water quality is minimized and internal waste treatment processes are emphasized and encouraged. The advantages and disadvantages of biofloc systems compared to ponds and recirculating systems are summarized in Table.

Research with shrimp indicates that culture water contains growth-enhancing factors, such as microbial and animal proteins, that boost production. Flocs are a supplemental food resource that can be grazed by shrimp or tilapia between feedings of pelleted diets. A potential benefit of biofloc systems is the capacity to recycle waste nutrients through microbial protein into fish or shrimp. About 20 to 30 percent of the nitrogen in added feed is assimilated by fish, implying that 70 to 80 percent of nitrogen added as feed is released to the culture environment as waste. In biofloc systems, some of this nitrogen is incorporated into bacterial cells that are a main component of biofloc. Consumption of this microbial protein, in effect for a second time, contributes to growth. Research with shrimp and tilapia suggests that for every unit

Table 1. Advantages and disadvantages of biofloc systems compared to semi-intensive ponds and recirculating aquaculture systems (RAS). A check mark indicates an advantage or disadvantage of biofloc systems compared to most ponds or RAS.

	Ponds	RAS
Advantages		
Improved biosecurity	√	
Improved feed conversion	√	√
Improved water use efficiency	√	
Increased land-use efficiency	√	
Improved water quality control	√	
Reduced sensitivity to light fluctuations (weather)	√	
Disadvantages		
Increased energy requirement for mixing and aeration	√	√
Reduced response time because water respiration rates are elevated	√	√
Start-up period required	√	
Increased instability of nitrification		√
Alkalinity supplementation required	√	
Increased pollution potential from nitrate accumulation	√	
Inconsistent and seasonal performance for sunlight-exposed systems		√

of growth derived from feed, an additional 0.25 to 0.50 units of growth are derived from microbial protein in biofloc systems. In other words, 20 to 30 percent of shrimp or tilapia growth is derived from the consumption and digestion of microbial protein. This benefit is reflected in improved feed conversion, one of the best predictors of system profitability and business sustainability. However, the value of flocs in nutrition is limited at the highest levels of production intensity because the contribution of feed to growth of cultured animals is overwhelming.

Biofloc Management

The major component of biofloc is heterotrophic bacteria. The function of the biofloc is to reduce the nitrogenous metabolic waste (ammonia, nitrite) produced by shrimp feeding and production. Ammonia consumed by heterotrophic bacteria becomes protein, which can then be consumed by shrimp and converted into growth. Heterotrophic bacteria need carbon for ammonia to be assimilated. In addition to the commercial feed, a supplemental source of carbon must be added in order to stimulate production of the heterotrophic bacteria and reduce the nitrogenous waste.Shrimp feed has a carbon to nitrogen (C:N) ratio of approximately 7–10:1. Heterotrophic bacteria would prefer a ratio of approximately 12–15:1. Simple sugars or starches are added to increase the ratio and promote bacterial growth. Additives have included molasses, sugar, sucrose, and dextrose. Some producers use glycerin. Application rates will vary with the protein content of the feed and composition of the carbon source, but a good rule of thumb is that for every 1 kg of feed, about 0.5–1 kg of carbon source is required. Higher protein feed will need higher carbon supplementation. Actual applications must take into consideration the levels of ammonia and nitrites in the water.

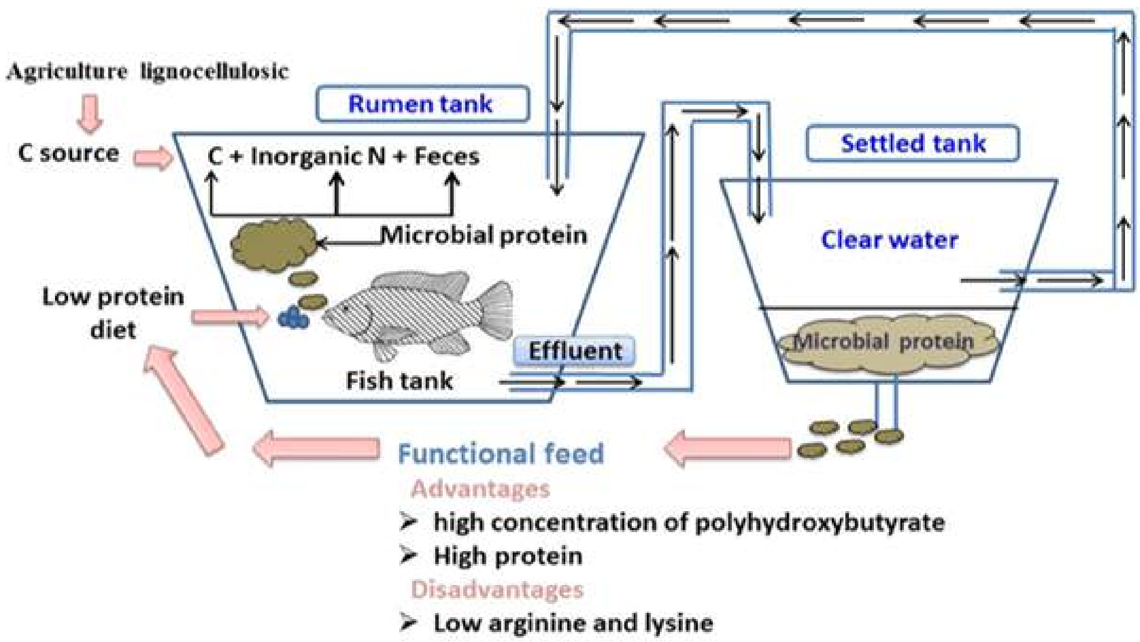

Fig.1. Biofloc rumen pond

For successful and efficient management of a biofloc farm have to get more idea about biofloc management. But the technique is not so complicated. Most simple and easily understandable explanation about biofloc is that heterotrophic bacteria will decompose waste materials and ammonia content of water and will be converted to bacterial biomass. Part of this highly nutritious biomass consumed by protozoa and other microorganisns will converted to their biomass. These microorganisms and bacteria remain in small floc and serves as very nutritious food of the cultured organisms. So biofloc system helps to maintain good water quality , decreases requirement of water exchange, decreases quantity of feed requirement(by about 20%) and helps to maintain biosecurity

Biofloc system of farming is now very popular in many countries of the world including Indonesia, Vietnam, Thailand, India etc.

Suitable Culture Species for Biofloc

A basic factor in designing a biofloc system is the species to be cultured. Biofloc systems work best with species that are able to derive some nutritional benefit from the direct consumption of floc. Biofloc systems are also most suitable for species that can tolerate high solids concentration in water and are generally tolerant of poor water quality. Species such as shrimp and tilapia have physiological adaptations that allow them to consume biofloc and digest microbial protein, thereby taking advantage of biofloc as a food resource. Nearly all biofloc systems are used to grow shrimp, tilapia, or carps. Channel catfish and hybrid striped bass are examples of fish that are not good candidates for biofloc systems because they do not tolerate water with very high solids concentrations and do not have adaptations to filter solids from water.

Basic types of biofloc systems

Few types of biofloc systems have been used in commercial aquaculture or evaluated in research. The two basic types are those that are exposed to natural light and those that are not. Biofloc systems exposed to natural light include outdoor, lined ponds or tanks for the culture of shrimp or tilapia and lined raceways for shrimp culture in greenhouses. A complex mixture of algal and bacterial processes control water quality in such "greenwater" biofloc systems. Most biofloc systems in commercial use are greenwater. However, some biofloc systems (raceways and tanks) have been installed in closed buildings with no exposure to natural light. These systems are operated as "brown- water" biofloc systems, where only bacterial processes control water quality.

Conclusion

Biofloc technology application offers benefits in improving aquaculture production that could contribute to the achievement of sustainable development goals. This technology could result in higher productivity with less impact to the environment. Furthermore, biofloc systems may be developed and performed in integration with other food production, thus promoting productive integrated systems, aiming at producing more food and feed from the same area of land with fewer input. The biofloc technology is still in its infant stage. A lot more research is needed to optimize the system (in relation to operational parameters) e.g. in relation to nutrient recycling, MAMP production and immunological effects. In addition, research findings will need to be communicated to farmers as the implementation of biofloc technology will require upgrading their skills.