BIOFLOC TECHNOLOGY FOR WATER QUALITY MANAGEMENT IN AQUACULTURE

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Introduction

In aquaculture systems, much of the nitrogen input enters the water column as total ammonia-nitrogen generated by feed is not fully converted into shrimp tissue. Generally, metabolites like ammonia-nitrogen and nitrite-nitrogen are generated during intensive aquaculture as a consequence of aquatic animal excretion, sediment mineralization and microbial process in water column. Nitrogen loss varied from 14.7% to 34.7% based on stocking density under zero water exchange culture system. The presence of TAN in water above 1.0 ppm can cause adverse health effects in aquatic animals and create environmental concerns if effluent is not properly treated. The metabolites are deleterious to the animal which causes increase in blood pH, reduction in oxygen content of blood, affects gills, causes stress, reduced feeding, retarded growth, poor survival and high susceptibility to disease. Many biological treatment systems have been developed to maintain low ammonia and nitrite-N concentrations in culture water.

Pathways to control ammonia in aquaculture pond environment

The three nitrogen conversion pathways by microbes for removal of ammonia nitrogen in aquaculture system are photoautotrophic removal by algae, autotrophic bacterial conversion of ammonia nitrogen to nitrate nitrogen and heterotrophic bacterial conversion of ammonia nitrogen directly to bacterial biomass (Biofloc). Phytoplankton based systems are attractive because of their simplicity and low operational cost but fail to sustain a stable operation because of periodic phytoplankton bloom and crash cycles. Nitrifying biofilters have been successfully employed in various aquaculture applications. Despite many advantages, the use of nitrifying bio filters remains costly. Currently, biofloc technology systems have been receiving attention because they feature high production, water quality control, and feed protein recycling simultaneously in the same culture unit Biofloc system leads to sustainable production through reduction of cost of feed and water exchange and protect the surrounding environment.

Biofloc Technology

The Biofloc technology (BFT) is based on the manipulation of microbial community through the addition of a carbon source that promotes the development of heterotrophic bacteria. These bacteria use the organic carbon and the inorganic nitrogen present in the water to produce their biomass by removing toxic ammonia from the culture system. This system facilitates the production of aquatic animals at high stocking densities in a sustainable and bio-secure fashion. In some cases, the protein content of feed can be reduced due to partial protein supplementation by the microbial community.

Biofloc as a bioremediator to improve water quality

Biofloc is nothing but aggregates of bacteria dominated by heterotrophic, organic material, inorganic flocculants and suspended algae. All of these microscopic organisms have their own function and interact between each other in the biofloc system to make the bioremediation process successful and maintain water quality during the culture. The algae serve as a food for the animal/pond stock and the bacteria promotes direct conversion of nitrogenous waste to simpler compounds. This process maintains or greatly improves the quality of pondwater. Improvement in waterquality drastically reduces the need to use large volume of additional water in the pond. This leads to sustainable activity that is in balance with the environment and reduces the cost of water and feed for the pond stock. The biological processes in biofloc system to improve waterquality are shown in the figure below.

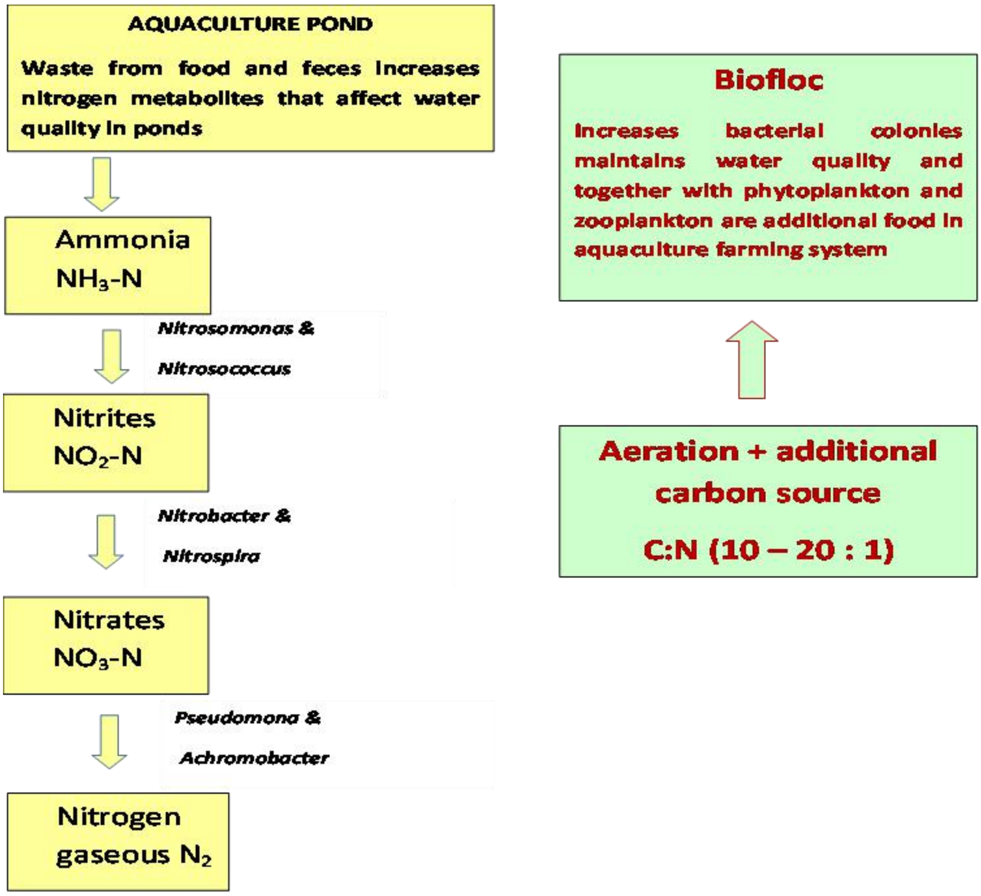

Fig. Biological processes in biofloc system to improve waterquality

Factors controlling ammonia concentration in Biofloc System

1. Balancing input C:N ratio

In biofloc systems a major factor that controls ammonia concentration is the C:N ratio off other inputs. A feed with 35 percent protein concentration has a relatively low C: N ratio of about 9 to 10:1. Increasing the C: N ratio to 12 to 15:1 favours the heterotrophic pathway for ammonia control. The low C: N ratio of feed can be augmented by adding supplemental materials with high C: N ratio or, by reducing feed protein content. At high C:N ratio, heterotrophic bacteria dominate autotrophic microorganisms, immobilize the ammonium ion for production of microbial protein and maintain inorganic nitrogen level in the water within the limit. Immobilization of ammonium by heterotrophic bacteria occurs much more rapidly because the growth rate and microbial biomass yield per unit substrate of heterotrophs are a factor 10 higher than that of nitrifying bacteria.

2. Type of carbon source

Capacity of the biofloc system to control water quality in the culture system and the nutritional properties of the flocs are influenced by the type of carbon source used to produce the flocs. Some of the carbon sources are tapioca flour, wheat flour, molasses, sugar etc.

3. Amount ofcarbon

The amount of carbon addition depends on several factors such as water quality, physiology and density of the animal, and solubility of carbon source. To operate biofloc system efficiently, C: N ratio has to be maintained in the ratio between 10:1 and 20:1. Under optimum C: N ratio, inorganic nitrogen is immobilized into bacterial cell while organic substances are metabolized.

4. Aeration and mixing of water

Constant intensive turbulent mixing is essential in a BFT system in order to keep the solid suspended in the water column at all times. Without mixing, bioflocs can settle out of suspension and form dense piles that rapidly consume nearby dissolved oxygen, creating an anaerobic zone. These zones can lead to the release of chemical compounds such as hydrogen sulphide, methane and ammonia that are toxic to shrimps and fish. In practice, aeration is used to supply oxygen and provide adequate mixing. Various configurations of aeration equipment are possible, depending on the specific form of biofloc system. In lined ponds or tanks, multiple paddle wheel aerators are arrayed to provide whole-pond circular mixing. Shrimp raceways in greenhouses often use banks of airlift pumps placed at intervals around raceways to aerate and circulate water. Diffused aeration can be used in small tanks. Devices that circulate water at low head, such as low-speed paddlewheels and airlift pumps, can be used. Biofloc shrimp ponds are aerated with 25 to 35 hp/ha, and some intensive tilapia systems are aerated with 100 to 150 hp/ha (Hargreaves, 2013). These intensive aeration rates could not be applied to earthen ponds without significant erosion, thus most biofloc systems are lined. Biofloc systems are not a good choice in areas where power supplies are unreliable or electricity is expensive.

Changes in water quality under biofloc system

Under biofloc system, ammonia and nitrite concentration are generally low due to the removal of these compounds by microbial community. Nitrate concentration was low due to the lower concentration of ammonia nitrogen available to the oxidation by nitrifying bacteria. The absorption of the reduced form of inorganic nitrogen by phytoplankton is probably the primary cause for high concentration of chlorophyll a concentrations in this system. The use of carbon sources in intensive systems promotes succession and dominance of bacteria over microalgae.

Physical-chemical characteristics of water under biofloc system

Temperature

Temperature is one of the most influential parameters in pond system. It affects metabolic rate of animal & microorganism, oxygen consumption, pH and concentration of ionized and un-ionized ammonia during culture. The optimum temperature range will depend on the animal species, bacteria adapted to the system temperature as well as seasonal and environmental variations. Biofloc system is more efficient when water temperature is between 28 and 30^{o}C. Nitrifying bacteria can support a range from 8-30^{o}C, but efficiency is reduced by 50% at 16^{o}C and by 80% at 10^{o}C.

Dissolved oxygen

Oxygen in aquatic system should be >5 ppm. In a biofloc system, as the algae and bacteria also have oxygen demand, dissolve oxygen should be maintained at 7-8 ppm to ensure proper functioning of the system.

pH

pH is to be maintained in the range between 7 and 8.5. Hydrated lime ($Ca\ (OH)_2$) is to be used to maintain alkalinity and pH above 100 ppm of $CaCO_3$ and 7.5, respectively in the Biofloc system. pH reduction generally occurs due to alkalinity consumption during ammonia–nitrate nitrogen conversion processes. According to Furtado *etal*. (2011), levels less than 100ppm of $CaCO_3$ and pH 7 for prolonged periods of time can affect the growth performance of shrimp in biofloc.

Alkalinity

Alkalinity is the capacity of water to buffer or resist changes in pH in response to additions of acid or base. Water in biofloc systems should be maintained with ample reserves of alkalinity because it is constantly depleted by the activity of nitrifying bacteria in nitrification. Once alkalinity is depleted, pH can drop steeply, inhibiting bacterial function, including important nitrifying bacteria. In this situation, ammonia accumulates to the point where shrimp feeding response will deteriorate. This limits daily feeding rate, feed conversion efficiency and ultimately production. Alkalinity should be kept between 100 and 150 ppm as $CaCO_3$ by regular additions of sodium bicarbonate. Other liming agents are less suitable. Every kilogram of feed added to the system should be supplemented with 0.25 kilogram of sodium bicarbonate.

Suspended solids, Settelable solids and volatiles

Bacteria depend on suspended solids as a substrate for adhesion and as a source of energy from carbon. In biofloc system, TSS in the range of 250-450 ppm ensures efficient bacterial activity and a good system to control ammonia without excessive water respiration. An excess of TSS affects the breathing process of animals, lead to stress or in extreme cases, lead to death by clogging gills. Culture of *L.vannamei* in biofloc system contained 453±50 ppm of TSS and 256±106 ppm of volatile solids improved shrimp production provided efficient exchange of oxygen. The desired range of settleable solids concentration is 10 to 15 mL/L for shrimp and 25 to 50 mL/L for tilapia under good biofloc system.

Turbidity

In aquaculture system, turbidity is due to suspended solids, phytoplankton, zooplankton and bacteria. Turbidity is measured by Secchi disk and the value of 35-40cm is acceptable. Turbidity of 75 to 150 NTU is comparable to the recommended settleable solids concentration provided that colour interference is not too severe.

Total Ammonia Nitrogen

It is the excretion product of feaces, urine, uneaten food, phytoplankton and zooplankton. Ammonia or non-ionized ammonia (gaseous) is considered as toxic when compared to ionized ammonia or ammonium ion (NH_4). The unionized form (NH_3) increases with a low oxygen concentration, high pH and high temperature. The recommended ammonia concentration in biofloc culture is less than 1.5ppm. In *L. vannamei,* ammonia nitrogen concentration should be less than 1.2 and 6.5 ppm in post-larvae and juveniles (Frias *et al.*2000).

Nitrite nitrogen

The transformation process to ammonia nitrogen to nitrite nitrogen and their toxicity form depends on the amount of chlorides, temperature and oxygen concentration in water. Nitrite toxicity affects transport of oxygen, oxidation of important compounds and tissue damage. Nitrite-nitrogen concentration should be less than 2 ppm in biofloc culture (Perez-Rostro *et al.*2014).

Nitrate nitrogen

It is the end product of aerobic nitrification considered as less toxic. The toxicity of these compounds is due to its effects on osmoregulation and oxygen transport. Nitrate concentration should not exceed 10 ppm in biofloc culture.

Promising features of biofloc technology

Water is becoming scarce or expensive to an extent of limiting aquaculture development. Secondly, the release of polluted effluents into the environment is prohibited in most countries. Thirdly, severe outbreaks of infectious diseases led to more stringent biosecurity measures, such as reducing water exchange rates. Biofloc technology addresses the above issues making it a promising environment friendly solution.

Benefits accruing in pond water quality due to the use of biofloc technology

1. Improving water quality through removal of toxic nitrogen compounds such as ammonia and nitrite.
2. The water quality of a heterotrophic microbial-based production system containing bacterial flocs is more stable than that of a phytoplankton-based production system.
3. Biofloc technology makes it possible to minimize water exchange and water usage in aquaculture systems, through maintaining adequate water quality within the culture system.
4. Compared to conventional water treatment technologies used in aquaculture, biofloc technology provides a more economical alternative by reducing the water treatment expenses to the tune of about 30%.
5. Enhancing the farm biosecurity and health management through zero-water exchange and possible probiotic effect.

Conclusion

Aquaculture is expected to grow at a rapid pace all over the world in the coming years, hence there is a need to improve production, productivity while reducing the cost of culture and protecting the environment. Biofloc offers a lucrative combination of protecting the pond environment using natural resources, reducing the input cost of feed and effectively managing the additional water requirement, thereby providing an all-round economically feasible solution. In the future, biofloc will be one of the major technologies that will be widely utilized for pond water quality management.

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