AgriCos e-Newsletter
ISSN: 2582-7049
AgriCos e-Newsletter
Open Access Multidisciplinary Monthly Online Magazine
Volume: 04 Issue: 08 August 2023 Article No: 03

Environmental and Water Quality Management in Biofloc Technology

S. Manickavasagam, Stephen Sampath Kumar, M. Ponmani, S.Mariappan, and C.Sudhan
Tamil Nadu Dr.J.Jayalalithaa Fisheries University, Nagapattinam, Tamil Nadu

SUMMARY

Biofloc technology (BFT) is considered the new "blue revolution" in aquaculture. Such technique is based on in situ microorganism production which plays three major roles: (i) maintenance of water quality, by the uptake of nitrogen compounds generating in situ microbial protein; (ii) nutrition, increasing culture feasibility by reducing feed conversion ratio (FCR) and a decrease of feed costs; and (iii) competition with pathogens. The aggregates (bioflocs) are a rich protein-lipid natural source of food available in situ 24 hours per day due to a complex interaction between organic matter, physical substrate, and large range of microorganisms. This natural productivity plays an important role recycling nutrients and maintaining the water quality. The present chapter will discuss some insights of the role of microorganisms in BFT, main water quality parameters, the importance of the correct carbon-to-nitrogen ratio in the culture media, its calculations, and different types, as well as metagenomics of microorganisms and future perspectives.

INTRODUCTION

In a world where more than 800 million people continue suffering from chronic malnourishment and where the global population is expected to grow by another 2 billion to reach 9.6 billion people by 2050, it is important to meet the huge challenge of feeding our planet while safeguarding its natural resources for future generations. In this context, aquaculture plays a key role in eliminating hunger, promoting health, reducing poverty, as well as generating jobs and economic opportunities. According to FAO, the world food fish aquaculture production expanded at an average annual rate of 6.2% in the period 2000–2012 from 32.4 million to 66.6 million tons, in which Africa grew 11.7%, Latin America and the Caribbean 10%, Asia (excluding China) 8.2, and China 5.5. Employment in the sector has grown faster than the world's population. The sector provides jobs to tens of millions and supports the livelihoods of hundreds of millions. Fish continues to be one of the most traded food commodities worldwide. It is especially important for developing countries, sometimes worth half the total value of their traded commodities. On the other hand, global aquaculture has yet to face some serious challenges. For instance, aquaculture has been accused of being an unsustainable activity, because of the effluents discharged to the environment which contain excess of organic matter, nitrogenous compounds, toxic metabolites, and elevated rates of chemical and biochemical oxygen demands. Other serious accusations include the competition for land and water, the introduction of exotic species around the globe, the overexploitation of ocean fish stocks to obtain fishmeal and fish oil, the dispersion of pathogens, the development of antibiotic resistance genes, etc. Furthermore, aquaculture has to constantly deal with other problems, such as the shortage of ingredients and their price volatility. Thus, strategies aimed to overcome these challenges are required. In this regard, the modification of physicochemical variables of the culture system to favor the proliferation of particular biotic communities has been adopted not only to improve the recirculation of nutrients (and the consequent detoxification of the system) but also to use the biomass of such biotic communities as direct food source for the cultured organisms. These kinds of systems, also known as biofloc (BFT) technology systems, promise to solve some of the above challenges and revolutionize aquaculture.

Biofloc technology (BFT) in aquaculture

Biofloc technology (BFT) is as an environmentally friendly aquaculture technique based on in situ microorganism production. Fish and shrimp are grown in an intensive way (minimum of 300 g of biomass per square meter) with zero or minimum water exchange. In addition, continuously water movement in the entirely water column is required to induce the macroaggregate (biofloc) formation. Nutrients in water (in accordance with a known carbon-to-nitrogen ratio of 12–20:1) will contribute naturally to a heterotrophic microbial community formation and stabilization. These microorganisms play three major roles: (i) maintenance of water quality, by the uptake of nitrogen compounds generating in situ microbial protein; (ii) nutrition, increasing culture feasibility by reducing feed conversion ratio (FCR) and a decrease of feed costs; and (iii) competition with pathogens. BFT is considered the new "blue revolution" since nutrients can be continuously recycled and reused in the culture medium, benefited by the minimum or zero-water exchange. Also, the sustainable approach of such system is based on the high production of fish/shrimp in small areas. In addition, the bioflocs is a rich protein-lipid natural source of food available in situ 24 hours per day due to a complex interaction between organic matter, physical substrate, and large range of microorganisms. This natural productivity plays an important role recycling nutrients and maintaining the water quality. The consumption of biofloc by shrimp or fish has demonstrated innumerous benefits such as improvement of growth rate, decrease of FCR, and associated costs in feed. Regarding the applications, in the past years, BFT has been used in grow-out phase for tilapia and marine shrimp, nursery phase, freshwater prawn culture, broodstock formation and maturation in fish and shrimp, and as aquafeed ingredient also called as “biofloc meal”. In addition, recently BFT also has been applied in carp culture, catfish culture, and cachama culture.

Microorganisms as a tool for water quality management

Water quality maintenance and monitoring in aquaculture are the essential practices aiming at the success of the growing cycles. Temperature, dissolved oxygen (DO), pH, salinity, solids [total suspended solids (TSS) and settling solids], alkalinity, and orthophosphate are some examples of parameters that should be continuously monitored, especially in BFT. The comprehension and understanding of water quality parameters and its interactions in BFT are crucial to the correct development and maintenance of the production cycle. For example, safety ranges of pH, DO, total ammonia nitrogen (TAN), solids, and alkalinity will lead a health growth and avoid mortalities. N:P ratio (normally using nitrate and orthophosphate values) will influence the autotrophic community that will occur in the system (e.g., chlorophytes versus cyanophytes). The same recommended water quality parameters ranges and/or normal ranges observed for tropical species (e.g., marine shrimp Litopenaeus vannamei and tilapia) in BFT are presented in Table 1.

Table.1: Main water quality parameters monitored in BFT systems and its ideal and/or normal observed ranges.

Parameter	Ideal and/or normal observed ranges	Observations
Dissolved oxygen (DO)	Above of 4.0 mg L^{-1} (ideal) and at least 60% of saturation	For correct fish, shrimp, microbiota respiration, and growth
Temperature	28–30° (ideal for tropical species)	Besides fish/shrimp, low temperatures (~20° C) could affect microbial development
pH	6.8–8.0	Values less than 7.0 is normal in BFT but could affect the nitrification process
Salinity	Depends on the cultured species	It is possible to generate BFT, e.g., from 0 to 50 ppt
Total Ammonia Nitrogen	Less than 1 mg L^{-1} (ideal)	Toxicity values are pH dependent
Nitrite	Less than 1 mg L^{-1} (ideal)	Critical parameter (difficult to control). Special attention should be done, e.g., on protein level of feed, salinity, and alkalinity
Nitrate	0.5–20 mg L^{-1}	In these ranges, generally not toxic to the cultured animals
Orthophosphate	0.5–20 mg L^{-1}	In these ranges, generally not toxic to the cultured animals
Alkalinity	More than 100 mg L^{-1}	Higher values of alkalinity will help the nitrogen assimilation by heterotrophic Bacteria and nitrification process by chemoautotrophic bacteria
Settling solids (SS)	Ideal: 5–15 mL L^{-1} (shrimp), 5–20 (tilapia fingerlings) and 20–50 mL L^{-1} (juveniles and adult tilapia)	High levels of SS (measured in Imhoff cones) will contribute to the DO consumption by heterotrophic community and gill occlusion
Total suspended solids (TSS)	Less than 500 mg L^{-1}	Idem to SS

Carbon: Nitrogen (C:N) ratio and its application

The management of the carbon-to-nitrogen ratio (C:N) in BFT is normally divided in two phases: (i) initial and formation phase, utilizing a carbon-to-nitrogen ratio of 12–20:1, and (ii) maintenance phase, utilizing a carbon-to-nitrogen ratio of 6:1, according to the total ammonia nitrogen (TAN) values. In the beginning of culture period, high carbon-to-nitrogen ratio (12–20:1) in water is a key factor to promote and stabilize the heterotrophic community in BFT. High carbon concentration will induce the nitrogenous by-product assimilation by heterotrophic bacteria and also will supersede the carbon assimilatory capacity of algae, contributing to bacteria growth. Aerobic microorganisms are efficient in converting feed to new cell material (40–60% of conversion efficiency), rather than higher organisms (e.g., micro-herbivores, micro-carnivores, and deposit feeders) that spend about 10–15% to rise in weight. The system is considered "mature" (~30 to 50 days) when SS reaches at least 5 mL/L (measured using Imhoff cones) and TAN and nitrite peaks already occurred. To accelerate the water "maturation" (biofloc equilibrium), an inoculum of a previous BFT culture can be used once sanitary conditions are satisfactory. It is important to note that as long as the production cycles advance, nitrifying (chemoautotrophic) bacteria play a major role in N-compound control. In addition, suspended particles or solids (bioflocs) also will be increasing over time. With this information in mind, carbon addition could be reduced (or even stopped), preventing the excess of solids (bioflocs) in the cultured system that will lead an excessive DO consumption and shrimp/fish gill occlusions. For the maintenance phase, the monitoring of TAN values is an important tool for water quality maintenance. When values of TAN are higher than 1.0 mg L^{-1}, external carbon source application is recommended with a C:N ratio of 6:1. In such phase, the use of monosaccharide and oligosaccharide carbohydrate-rich types (e.g., molasses and other sugars) is recommended due to the faster bacteria assimilation and consequently TAN reduction. Same examples of C:N calculations for the phase I and phase II are presented as followed. For both examples, the carbon content of the feed will be considered 50% (based on dry matter). For the carbon source, molasses was chosen and its content in such case is also 50%. It is important to note that the carbon content will change according to the dry matter composition and type of carbon source. In a practical way, dry matter of the feed will be 90%. Fish and shrimp assimilation will be considered 35 and 20%, respectively.

CONCLUSIONS

Biofloc technology will enable aquaculture grow toward an environmentally friendly approach and biosecurity. Consumption of microorganisms in BFT reduces FCR and consequently costs in feed. Also, microbial community is able to rapidly utilize dissolved nitrogen leached from shrimp/fish feces and uneaten food and convert it into microbial protein, maintaining the water quality. The physical, chemical, and biological interactions that occur into the biofloc systems are complex; further studies can elucidate specific phenomena and their possible applications to other biotechnological fields.

REFERENCES

Avnimelech Y. Biofloc Technology – A Practical Guide Book. 3rd ed. The World Aquaculture Society, Baton Rouge, Louisiana, United States. 2015.

Avnimelech Y. Carbon nitrogen ratio as a control element in aquaculture systems. Aquaculture. 1999;176:227–235.

Avnimelech Y. Feeding with microbial flocs by tilapia in minimal discharge bioflocs technology ponds. Aquaculture. 2007;264:140–147.

Ebeling JM, Timmons MB, Bisogni JJ. Engineering analysis of the stoichiometry of photoautotrophic, autotrophic, and heterotrophic removal of ammonia–nitrogen in aquaculture systems. Aquaculture. 2006;257(1):346–358.

Emerenciano M, Cuzon G, Goguenheim J, Gaxiola G, Aquacop. Floc contribution on spawning performance of blue shrimp Litopenaeus stylirostris. Aquaculture Research. 2012a;44:75–85.

FAO (Food and Agriculture Organization of the United Nations). The State of World Fisheries and Aquaculture 2014. Opportunities and Challenges. 2014; p. 223. Available at http://www.fao.org

Martínez-Córdova LR, Emerenciano M, Miranda-Baeza A, Martínez-Porchas M. Microbial-based systems for aquaculture of fish and shrimp: an updated review. Reviews in Aquaculture. 2015;7(2):131–148.

Martínez-Córdova LR, Martínez-Porchas M, Emerenciano M, Miranda-Baeza A, Gollas- Galván T. From microbes to fish the next revolution in food production. Critical Reviews in Biotechnology. 2016; Early Online: 1–9.

Martínez-Porchas M, Martinez-Córdova LR. World aquaculture: environmental impacts and troubleshooting alternatives. The Scientific World Journal. 2012;389623:1–9.

Martínez-Porchas M, Vargas-Albores F. Microbial metagenomics in aquaculture: a potential tool for a deeper insight into the activity. Reviews in Aquaculture. 2015 (online published first 6 July 2015).

Naylor RL, Williams SL, Strong DR. Aquaculture – A gateway for exotic species. Science. 2001;294(5547):1655–1656.

Schveitzer R, Arantes R, Costódio PF, Espírito Santo CM, Arana LV, Seiffert WQ, Andreatta ER. Effect of different biofloc levels on microbial activity, water quality and performance of Litopenaeus vannamei in a tank system operated with no water exchange. Aquacultural Engineering. 2013;56:59

Vinatea L, Gálvez AO, Browdy CL, Stokes A, Venero J, Haveman J, Lewis BL, Lawson A, Shuler A, Leffler JW. Photosynthesis, water respiration and growth performance of Litopenaeus vannamei in a super-intensive raceway culture with zero water exchange: interaction of water quality variables. Aquacultural Engineering. 2010;42:17–24.