BIOFLOC TECHNOLOGY –THE FUTURISTIC TECHNOLOGY FOR IMPROVING THE ECOLOGICAL & ECONOMIC SUSTAINABILITY OF AQUACULTURE

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Abstract: As the human population continues to grow, food production industries such as aquaculture will need to expand as well. In order to preserve the environment and the natural resources, this expansion will need to take place in a sustainable way. The expansion of the aquaculture production is restricted due to the pressure it causes on the environment by the discharge of waste products in the water bodies and by its dependence on fish oil and fishmeal. Aquaculture using bio-flocs technology (BFT) offers a solution to both problems. It combines the removal of nutrients from the water with the production of microbial biomass, which can in situ be used by the culture species as additional food source. Understanding the basics of bio-flocculation is essential for optimal practice. Cells in the flocs can profit from advective flow and as a result, exhibit faster substrate uptake than the planktonic cells. The latter mechanisms appear to be valid for low to moderate mixing intensities as those occurring in most aquaculture systems. Biofloc technology is a technique of enhancing water quality in aquaculture through balancing carbon and nitrogen in the system. The technology has recently gained attention as a sustainable method to control water quality, with the added value of producing proteinaceous feed in situ. In this review, we will discuss an ecological effects of the bio-floc technology, evaluate economic sustainability and identify some challenges for future research.

Keywords: Aquaculture, Biofloc, Ecological, Economic.

Introduction: Aquaculture is currently the fastest growing food producing sector in the world. The contribution of aquaculture to the world total fish production reached 44.1 percent in 2014 [1]. Through the use of intensive aquaculture, production of both freshwater and marine food fish has been increased significantly. As a result, the requirement for more sustainable and environmentally friendly management and culture practices remains fully necessary. Moreover, the expansion of aquaculture is also restricted due to land costs and by its strong dependence on fishmeal and fish oil [2]. Such ingredients are one of the prime constituents of feed for commercial aquaculture. Feed costs represent at least 50% of the total aquaculture production costs, which is predominantly due to the cost of protein component in commercial diets [3]. One such environmentally friendly aquaculture system is called Biofloc Technology (BFT) [4]. In these systems, a co-culture of heterotrophic bacteria and algae is grown in flocs under controlled conditions within the culture pond [5]. In BFT, minimum water discharge and reuse of water prevent environment degradation and convert such system in a real "environmentally friendly system" with a "green" approach. Compared to conventional water treatment technologies used in aquaculture, biofloc technology provides a more economical alternative (decrease of water treatment expenses in the order of 30%), and additionally, a potential gain on feed expenses (the efficiency of protein utilization is twice as high in biofloc technology systems when compared to conventional ponds), making it a low-cost sustainable constituent to future aquaculture development [6].

Types of biofloc system: There are few types of biofloc systems used in both commercial aquaculture or evaluated in research. Biofloc systems that are exposed to natural light include outdoor, lined ponds or tanks that are used for the culture of shrimp or tilapia hence these systems are also known as the "green-water" biofloc systems due to the green discoloration of the water by the algae community. However, some biofloc systems are not exposed to natural light but instead are installed indoor with no exposure to natural light. This system operate as "brown-water" biofloc system where only bacterial processes control the water quality in the system [7].

How biofloc technology works: Bioflocs are macroaggregates (flocs) of bacteria, algae, protozoa (also known as zooplankton) and particulate organic matter such as uneaten food and feces. The flocs are held together by a loose matrix of mucus secreted by the bacteria, bound by filamentous microorganisms or held together by electrostatic attraction (Hargreaves, 2013). Phytoplankton in the biofloc system could either be introduced into the system through the water that is used during the system start-up or inoculated into the system from a phytoplankton stock. In a green-water biofloc system, phytoplankton can help to control the water quality by uptake of toxic substances like ammonia-nitrogen. Being autotrophic, phytoplankton can also perform photosynthesis in the presence of sunlight, thereby enriching the system with oxygen produced [7].

Factors influencing floc formation and floc structure in bio-flocs technology: The knowledge on how to promote floc formation in activated sludge systems can be used for application in BFT. Yet, the parameters listed in Table 1 may need adjustment to obtain good aggregation and high quality of the bio-flocs together with optimal growth conditions for the aquaculture organisms.

Table I. Main operational parameters for bio-flocs technology based aquaculture and their manipulation.

Parameter	Floc parameters influenced	Manipulation possibilities	Related to
Mixing intensity/shear rate	Floc structure and final floc size	Choice of power input (W m^{-3}) Aeration device	Dissolved oxygen
Organic carbon source (e.g. glucose, acetate, starch)	Chemical floc composition (fatty acids, lipids, protein, polyhydroxyalkanoates)	Type of organic carbon source	Organic loading rate Dissolved oxygen
Organic loading rate	Microbial floc composition (filamentous vs. floc forming bacteria) Chemical floc composition (polyhydroxyalkanoates)	Feeding strategy (continuous feeding or regular interval feeding)	Dissolved oxygen
Dissolved oxygen (DO)	Microbial floc composition (filamentous vs. floc forming bacteria) Floc structure and floc volume index	Choice of power input (W m^{-3}) Aeration device Floc production in the pond	Mixing intensity Organic carbon source
Temperature	Floc structure and activity	Addition of heat	Dissolved oxygen
pH/ionics	Stability of the flocs	Addition of acid/base	Alkalinity Conductivity

Table II. Different carbon sources applied on BFT system (Source: [8])

Carbon source	Culture specie
Acetate	*Macrobrachium rosenbergii*
Cassava meal	*Penaeus monodon*
Cellulose	Tilapia
Corn flour	Hybrid bass and hybrid tilapia
Dextrose	*Litopenaeus vannamei*
Glycerol and Glycerol+*Bacillus*	*M. rosenbergii*
Glucose	*M. rosenbergii*
Molasses	*L. vannamei and P. monodon*
Sorghum meal	Tilapia
Tapioca	*L. vannamei* and *M. rosenbergii*
Wheat flour	Tilapia (*O. niloticus*)
Wheat bran + molasses	*Farfantepenaeus brasiensis, F. paulensis and F. Duorarum*
Starch	Tilapia *O. niloticus x O. aureus* and tilapia (Mozambique)

Table III. Proximate analysis of biofloc particles in different studies (Source: [9])

Crude protein (%)	Carbohydrates (%)	Lipids (%)	Crude fiber (%)	Ash (%)
43.0	-	12.5	-	26.5
31.2	-	2.6	-	28.2
12.0-42.0	-	2.0 - 8.0	-	22.0 -46.0

31.1	23.6	0.5	-	44.8
26.0-41.9	-	1.2-2.3	-	18.3- 40.7
30.4	-	1.9	12.4	38.9
49.0	36.4	1.13	12.6	13.4
38.8	25.3	<0.1	16.2	24.7
28.8 - 43.1	-	2.1 - 3.6	8.7 - 10.4	22.1 - 42.9
30.4	29.1	0.5	0.8	39.2
18.2-29.3	22.8-29.9	0.4-0.7	1.5-3.5	43.7-51.8
18.4-26.3	20.2-35.7	0.3-0.7	2.1-3.4	34.5-41.5
28.0-30.4	18.1-22.7	0.5-0.6	3.1-3.2	35.8-39.6

Applications in aquaculture:

5.1 **Nursery and grow-out:** BFT has been applied successfully in nursery phase in different shrimp species such as *L. vannamei*, *P. monodon* , *F. paulensis*, *F. brasiliensis* and *F. setiferus*. The primary advantage observed is related to a better nutrition by continuous consumption of biofloc, which might positively influence grow-out performance *a posteriori*, but was not always the case. In grow-out, BFT has been also shown nutritional and zootechnical benefits. In was estimated that more than 29% of the daily food intake of *L. vannamei* consisted of microbial flocs, decreasing FCR and reducing costs in feed [10].

5.2 **Breeding:** The BFT has been successfully applied for grow-out, but little is known about biofloc benefits on breeding. For example, in the shrimp industry with the global spread of viruses, the use of closed-life cycle broodstock appeared as a priority to guarantee biosecurity, avoiding vertical transmissions. [11].

5.3 **The "natural probiotic" effect of biofloc:** Biofloc can be a novel strategy for disease management in contrast to conventional approaches such as antibiotic, antifungal, probiotic and prebiotic application. The "natural probiotic" effect in BFT could act internally and/or externally against, i.e., to *Vibrio sp.* And ectoparasites, respectively. [12].

5.4 **Aquaponics:** Aquaponics is a sustainable food production system that combines a traditional aquaculture with hydroponics in a symbiotic environment. The water is efficiently recirculated and reused for maximum benefits through natural biological filtration and recirculation. The waste that is excreted by aquatic species or uneaten feed is naturally converted into nitrate and other beneficial nutrients in the water. [13].

Conclusion: A variety of beneficial features can be ascribed to biofloc technology, from water quality control to in situ feed production and some possible extra features. Biofloc technology offers aquaculture a sustainable tool to simultaneously address its environmental, social and economical issues concurrent with its growth. Researchers are challenged to further develop this technique and farmers to implement it in their future aquaculture systems. The basics of the technology is there, but its further development, fine-tuning and implementation will need further research and development from the present and future generation of researchers, farmers and consumers to make this technique a keystone of future sustainable aquaculture.

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