ISSN (Online): 2091-2609
DOI Prefix: 10.3126/ijasbt

International Journal of Applied Sciences and Biotechnology (IJASBT)

Mini Review

Bio-Floc Technology: Prospects & Challenges in Fish Farming of Nepal

Prajina Neupane[1*], Madhusudhan Adhikari[1], Manita Kumari Thapa[1], Astha Kiran Pandeya[2]

[1]Faculty of Agriculture, Agriculture and Forestry University, Chitwan, Nepal
[2]Department of Aquaculture, Agriculture and Forestry University, Chitwan, Nepal

Article Information

Received: 12 May 2020
Revised version received: 12 June 2020
Accepted: 15 June 2020
Published: 25 June 2020

Cite this article as:
P. Neupane et al. (2020) Int. J. Appl. Sci. Biotechnol. Vol 8(2): 140-145. DOI: 10.3126/ijasbt.v8i2.28933

***Corresponding author**
Prajina Neupane,
Faculty of Agriculture, Agriculture and Forestry University, Chitwan, Nepal
Email: neupaneprajina@gmail.com

Abstract

Bio-floc technology is the blue revolution in aquaculture & new technique of enhancing water quality & utilizing feed wastes in the aquaculture system. It follows the concept of conversion of ammonium in addition to organic nitrogenous wastes into bacterial biomass in where heterotrophic bacterial growth is stimulated & nitrogen uptake through the production of microbial proteins is promoted by the addition of carbohydrates to the pond. Nitrogen generated by uneaten feed and excreta of cultured organisms is converted into proteinaceous feed available for those same organisms. This technique recycles nutrients & nitrogenous wastes by maintaining a high carbon: nitrogen ratio and provides essential & higher quality nutrition to the shrimps & fishes in achieving fast growth, lesser FCR & possibility to prevent diseases. Water requirement in BFT is extremely less & it is advantageous than the conventional system where there is continuous water & nutrient recycling, lower FCR. On the other hand, many challenges are existing in practicing bio-floc in Nepal as it requires frequent pond monitoring by the technical manpower. The choice of carbon source should be made wisely and correctly as the performance of fish and water quality in the bio-floc ponds depend highly upon carbon source. Further, vitamins required for fish may not be produced by microbes thus needed to identify them and supply through the feed. However, the practice of bio-floc technology will be proven worth for farmers in Nepal.

Keywords: Bio-floc; FCR; Microbial; Nitrogen; Pond; Aquaculture

Introduction

Bio-floc technology is considered as a blue revolution in aquaculture which is a technique of enhancing water quality through the addition of extra carbon to the aquaculture system, through an external carbon source or elevated carbon content of the feed (Crab R, 2012). BFT is purely a new ongoing technique of commercial fish farming systems in the case of Nepal. BFT was first developed in the early 1970s at Ifremer-COP (French Research Institute for Exploitation of the Sea, Oceanic Center of Pacific) with different penaeid species including Penaeus monodon, *Fenneropenaeus merguiensis*, *Litopenaeus vannamei* and *L. stylirostris* (Emerenciano, (2013)). Indonesia has the highest number of farms using bio-floc or semi-bio-floc technology in the world. Despite the many benefits of bio-flocs, only about 20% to 25% of the shrimp farms & fish farming are successfully using bio-floc in the world. In Nepal, BFT has been initiated first in Chitwan (Tandi), Biratnagar along with a pilot project in Kathmandu too.

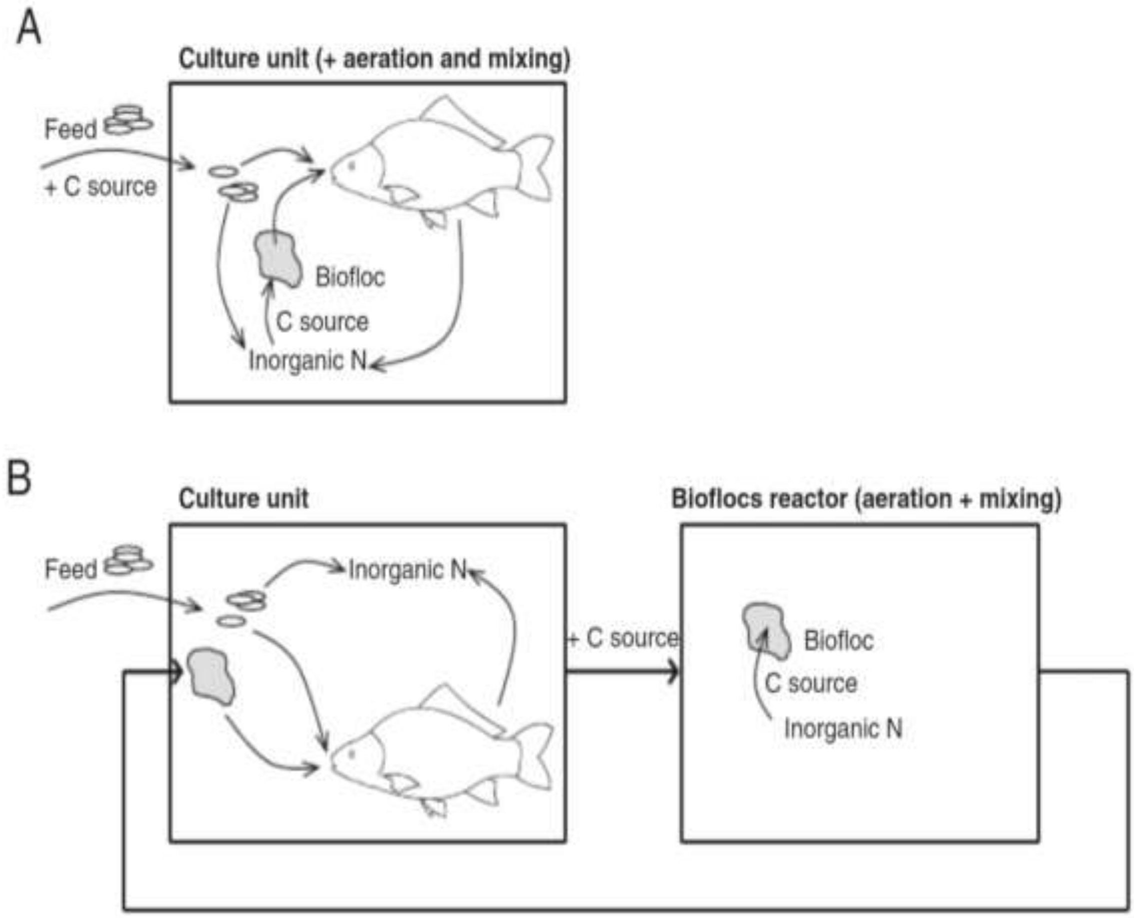

Fig. 1: Schematic representation of how bio-flocs can be implemented in aquaculture systems. (A) Integration of bio-flocs within the culture unit by using feed with a relatively low N content and/or the addition of a carbon source. (B) Use of a separate bio-flocs reactor. The wastewater from the culture tank is brought into the bio-floc reactor, where a carbon source is added to stimulate bio-floc growth. The water of the bio-floc reactor can be recirculated into the culture tank and/or bio-flocs can be harvested and used as a supplementary feed.

Bio-floc Technology

BFT follows the concept of conversion of ammonium in addition to organic nitrogenous wastes into bacterial biomass when Carbon & Nitrogen are balanced in the solution. Heterotrophic bacterial growth is stimulated & nitrogen uptake through the production of microbial proteins is promoted by the addition of carbohydrates to the pond (Avnimelech, 1999). As a result of bacterial growth, a decrease in ammonium concentration is more rapid than nitrification because the growth rate & microbial biomass yield per unit substrate of heterotroph are factor 10 higher than nitrifying bacteria (Hargreaves, 2006). Suspended growth in pond consists of a conglomeration of heterogeneous bacteria, algae, fungi, protozoans, metazoans, rotifers, copepods, nematodes, colloids, organic polymers, particulate organic matter such as uneaten feed, feces, and detritus. Bio-floc varies in size from 1-200µm and can reach more than 1000µm too. They are irregular in shape, easily compressible, highly porous and permeable to fluids. Floc comprises of 2-20% living microbial cells, 60-70% organic matter, and 30-40%total inorganic matter. A typical bio-floc contains four components: Bacterial colony, Filamentous bacteria, Absorbed matter and Algae.

Concept of Bio-floc Technology

The main objective of BFT is to recycle nutrients & nitrogenous wastes by maintaining a high carbon: nitrogen ratio. Carbon sources such as molasses, wheat bran & cellulose are responsible for bacterial growth and maintaining the C: N ratio in the culture system. The BFT, not only maintain water quality but also provide essential & higher quality nutrition to the shrimps & fishes in achieving fast growth, lesser FCR & possibility to prevent diseases (Suneetha *et al.*, 2018). Different factors like temperature, pH, dissolved oxygen, organic loading rate, etc. influence the floc formation in the pond.

This approach seems to be a practical and inexpensive means of reducing the accumulation of inorganic nitrogen in the pond. Nitrogen control is induced by feeding bacteria with carbohydrates, and subsequent uptake of nitrogen from the water, to synthesize microbial proteins. The relationship among the addition of carbohydrates, the reduction of ammonium and the production of microbial proteins depends on the microbial conversion coefficient, the C: N ratio in the microbial biomass, and the carbon contents of the added material (Avnimelech, 1999).

Working Mechanism

In BFT, heterotrophic bacteria feed on organic matter.

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + \text{Energy}$$

As bacteria are made of protein, they need nitrogen so they use the chemical energy in organic substrates & consume oxygen (though there are anaerobic bacteria).

Conditions for Bacteria

Bacteria need a lot of available food. The pond must be loaded with organic residues & the pond should be fully aerated (needed for proper fish growth). Further, the pond should be well mixed with its all components (typically 24 hours a day). Similarly, the number of bacteria in such ponds must be 10^6 up to 10^9 in one cm3 for proper functioning. The pond becomes a biotechnological industry corresponding to bio-floc technology.

Nutritional Composition in Bio-floc:

Bio-floc has good nutritional value. The dry weight protein ranges from 25-50%, fat ranges from 0.5-15% and it is also a good source of vitamins and minerals, especially phosphorous. It has a similar effect to probiotics (microorganisms introduced to the body with a purpose to gain health benefits from them; *Lactobacillus*, *Lactococcus*). The dried bio-floc is intended to replace the fishmeal or soybean in the feed.

In a study using molasses as a carbon source, 28.7-43.1% of protein & 2.11 and 3.625% of lipids were reported in bio-floc used to culture *Litopenaeus vannamei* whereas in another study cultured tilapia with wheat flour, was obtained protein level of 38%, & for lipids of 3.16 and 3.23% (Becerril-Cortés *et al*., 2018). Rotifers, ciliates, protozoa, nematodes, copepods, bacteria, microalgae & yeast form diversified bio-floc taking into consideration their nutritional contribution & ecological importance. For example, microalgae, protein content may vary from 30-65% of dry weight. In chlorophytes & diatoms, saturated fatty acids can constitute 15-40% of total fatty acids, meanwhile, green microalgae show a low concentration of monosaturated fatty acids & high polyunsaturated concentrations. Proximal composition of some planktonic species that are found in bio-floc shows that rotifers can contain 54-60% of crude proteins whereas Cladocerans 50-68% and copepods 70-71% (Becerril-Cortés *et al*., 2018).

Flowchart of Feeding a fish in Bio-floc Technology:

Schematic calculation of the daily amount of carbon needed to remove the nitrogen wasted from uneaten feed and excretion from the animals by Bio-floc is shown in Fig. 2.

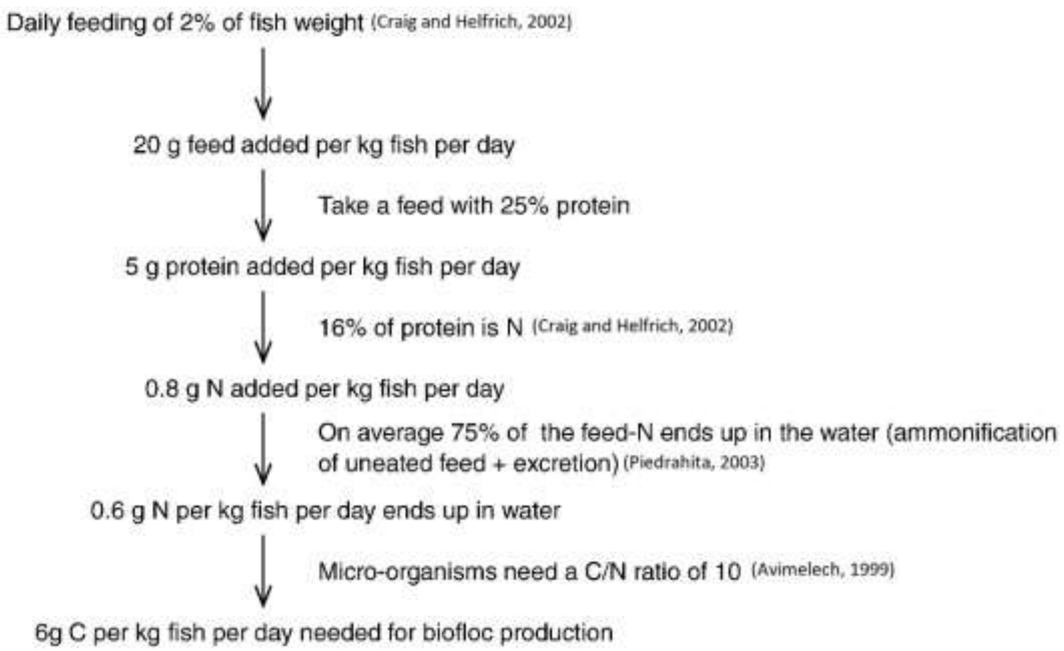

Fig. 2: Schematic calculation of the daily amount of carbon needed to remove the nitrogen wasted from uneaten feed and excretion from the animals by Bio-floc.

The addition of a carbonaceous substrate was found to reduce inorganic nitrogen in shrimp experimental tanks and in tilapia commercial-scale ponds. It was found in tilapia ponds that the produced microbial proteins are taken up by the fish. Thus, part of the feed protein is replaced and feeding costs are reduced (Avnimelech, 1999)

Unlike carbon dioxide, nitrogenous metabolites cannot be released to the air by diffusion or forced aeration in the pond. The intensification of aquaculture systems is, therefore, inherently associated with the enrichment of the water concerning ammonium and other inorganic nitrogenous compounds.

Strengths of Bio-floc Technology

The strength of the bio-floc technology lies in its 'cradle to cradle' concept, in which the term waste, in fact, does not exist. Translated in bio-floc terms, 'wastes'- nitrogen generated by uneaten feed and excreta of cultured organisms is converted into proteinaceous feed available for those same organisms (McDonough and Braungart, 2002).

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 (Avnimelech, 2009). In conventional fish farming systems, it requires frequent maintenance of water quality which is a tedious job but with the use of bio-floc technology bacterial flocs are recruited in maintaining water quality. Unlike the conventional techniques such as biofilters, biofloc technology supports nitrogen removal even when organic matter and biological oxygen demand of the system water is high (Avnimelech, 2009). Water requirement in BFT is extremely less compared to the conventional system as there is a recycling of water, maintaining quality & there is less or no water exchange. This system is compatible in highly urbanized areas where the land resource is scarce but make use of highly sophisticated technology.

Feed Utilization

Most available fish feeds have Feed Conversion Ratio (FCR) of 3, i.e. to produce 1 kg live weight of fish 3 kg of dry feed should be fed. The FCR for Wheat bran (WB) and Rice-Wheat bran (RWB) is significantly higher than that in bio-floc technology with periphytons. Thus bio-floc makes use of lesser feed to produce the same quantity of fish as in the conventional system.

Total Fish Production

In the case of Tilapia, the biomass of Tilapia can be harvested up to 200-300 tons/ha in a well-managed pond with BFT. In a treatment using Crude fiber (CF), Wheat Bran (WB), Rice-Wheat bran (RWB) and Bio floc technology (BFT), the highest production (3803 kg/ha) was recorded in commercial Tilapia feeding on CF and the lowest production (2883 kg/ha) was recorded in BFT using periphyton. But, economically, BFT proved to be profitable due to reduced FCR (Nahar, 2015).

Economic Analysis

From a simple economic analysis performed to estimate net profit from BFT culture, it was found that the net profit generated from the 6 months culture period was TK 48,519, 94,749.2, 99,453.3 and 71,230.7/acre in CF, WB, BFT, and RWB respectively. The highest net profit of TK (Taka-Currency of Bangladesh) 99,453.3/acre/6 months was obtained in BFT receiving periphyton and the lowest was TK 48,519.0/acre/6 months in CF receiving commercial Tilapia feed (Nahar, 2015).

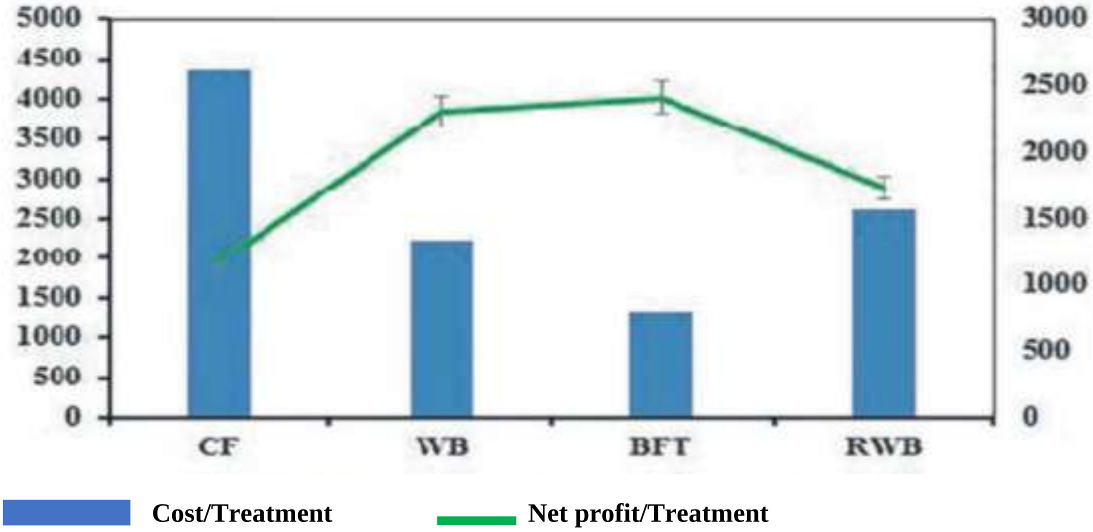

Fig. 3: The cost-benefit ratio of monosex Tilapia farming in Bangladesh for a period of 6 months from March 2014 to August 2014.

Advantages of Bio-floc Technology

- BFT is an eco-friendly culture system.
- It reduces environmental impact.
- It improves land and water use efficiency
- It is limited or zero water exchange
- Ensures higher productivity
- This promotes higher biosecurity.
- It reduces water pollution and the risk of introduction and spread of pathogens
- It is cost-effective feed production.
- It reduces the utilization of protein-rich feed and the cost of standard feed.
- It reduces the pressure on capture fisheries i.e., the use of cheaper food fish and trash fish for fish feed formulation. (https://vikaspedia.in/agriculture/fisheries/fish-production/culture-fisheries/types-of-aquaculture/biofloc)

Challenges of Bio-floc Technology

Neither technology is without drawbacks and nor is Bio-floc Technology. A major obstacle is to convince Nepalese farmers to implement the technique since the concept of bio-floc technology goes against common wisdom that the water in the pond has to be clear (Avnimelech Y. , Biofloc Technology —A Practical Guide Book., 2009). On the other hand, water has become scare limiting aquaculture development, the release of polluted effluents into the environment has been restricted and the outbreak of infectious disease has led to more stringent biosecurity measures, such as reducing water exchange rates.

A very important aspect of the implementation of bio-floc technology in aquaculture is the monitoring of the ponds. Bio-floc technology is not yet fully predictable and can, therefore, be risky to implement at the farm level. Possible monitoring tools are the concentration of total suspended solids or bio-flocs, and the settleability of the bio-floc which can be measured both quickly and easily (De Schryver, 2008). Molecular monitoring can also be used but is not applicable in real bio-floc farms due to time and cost limitations in the case of Nepal.

The performance of fish and water quality in the bio-floc ponds depends highly upon the carbon source supplied to the bio-flocs. Hence, the choice of carbon source should be made wisely and correctly. Different carbon source stimulates specific protozoa, bacteria, and algae and hence influence the microbial composition and community organization of the bio-flocs and also their nutritional properties. One also needs to take into account, the ability of cultured fish to tolerate high suspended solid concentration, as this may adversely affect the growth of certain fish species.

Another important factor that is essential for the growth and survival of aquaculture species are vitamins. In an experiment, vitamin C concentrations in bio-flocs found to be ranging from 0 to 54 microgram/gram dry matter which is below the required concentration for fish and shrimp (Crab, 2010). Besides vitamin C, other vitamins such as thiamine, riboflavin, pyridoxine, pantothenic acid, nicotinic acid, biotin, folic acid, vitamin B12, inositol, choline, vitamin A, vitamin D3, vitamin E and vitamin K, are usually not sufficiently synthesized by the

cultured organism either and need to be supplied through the feed.

Hence, it needs to be confirmed to what extent the bio-flocs can contribute to the supply of these essential nutrients and supplemental feed should be provided accordingly.

Disadvantages of Bio-floc Technology

- BFT requires increased energy requirement for mixing and aeration
- It has reduced response time because water respiration rates are elevated
- It requires a start-up period.
- It requires alkalinity supplementation
- Leads to increased pollution potential from nitrate accumulation
- This leads to inconsistent and seasonal performance for sunlight-exposed systems. (https://vikaspedia.in/agriculture/fisheries/fish-production/culture-fisheries/types-of-aquaculture/biofloc

Conclusion & Recommendation

In contrast, BFT (Bio-floc technology) will enable aquaculture to grow towards an environment-friendly approach and biosecurity. Consumption of microorganisms in BFT reduces FCR and finally lowers the farmer`s costs in the feed. Similarly, the microbial community can rapidly dissolve nitrogen leached from fish feces and uneaten food & convert it into microbial protein, maintaining water quality. The physical, chemical & biological interactions that occur into the bio-floc systems are complex which can elucidate specific phenomena and their possible applications to other biotechnological fields from further studies. It helps in maintaining water quality by continuous recycling, ensures less FCR through feces & waste recycling in the pond. Thus, it has proven more profitable than conventional fish farming as well as more production is ensured with low feed input. This technique is highly suitable in urban areas where there is scarce land & water but advanced technology. Nepalese farmers with poor economic conditions can also afford bio-floc technology ultimately ameliorating their economic status. Now, it is our turn to incorporate bio-floc technology in an existing farming system for intensive fish production with low feed, water & land resources to establish a blue revolution in a country like Nepal too.

Author`s Contribution

Prajina Neupane & Madhusudhan Adhikari designed the research plan; Manita Thapa performed experimental works & collected the required data. Madhusudhan Adhikari & Manita Thapa analyzed the data; Prajina Neupane, Madhusudhan Adhikari & Manita Thapa prepared the manuscript, critical revised and finalized the manuscript. Final form of manuscript was approved by all authors.

Conflict of Interest

The authors declare that there is no conflict of interest with any of the present publication.

Acknowledgement

We want to acknowledge Dr. Narayan Prasad Pandit: Ph.D., Assistant professor, Department of Aquaculture, Faculty of Animal Science, Veterinary Science & Fisheries (Agriculture and Forestry University) who guided us and provided suggestions. Similarly, a very sincere thanks to all the members of the Department of Aquaculture, AFU Rampur, Chitwan.

References

Avnimelech Y (1999) Carbon/nitrogen ratio as a control element in aquaculture systems. *Aquaculture* **176**(3-4): 227–235. DOI: 10.1016/S0044-8486(99)00085-X

Avnimelech Y (2009) *Biofloc Technology —A Practical Guide Book*. Baton Rouge, Louisiana, United States. 182 pp: The World Aqua-culture Society.

Becerril-Cortés D, Monroy-Dosta MDC, Emerenciano MGC, Castro-Mejía G, Bermúdez BSS and Correa GV (2018) Effect on nutritional composition of produced bioflocs. *International Journal of Fisheries and Aquatic Studies* **6**(2): 541-547.

Crab R (2010) Bioflocs technology: an integrated system for the removal of nutrients and simultaneous production of feed in aquaculture. (Doctoral dissertation, Ghent University)178pp.

Crab R, Defoirdt T, Bossier P and Verstraete W (2012) Biofloc technology in aquaculture: beneficial effects and future challenges. *Aquaculture* **356**: 351-356. DOI: 10.1016/j.aquaculture.2012.04.046

De Schryver PC (2008) The basics of bio-flocs technology: the added value for aquaculture. *Aquaculture* **277**: 125-137. DOI: 10.1016/j.aquaculture.2008.02.019

Emerenciano M, Gaxiola G and Cuzon G ((2013)). Biofloc Technology (BFT): A Review for Aquaculture Application and Animal Food Industry. *Biomass now-cultivation and utilization* **30**: 301-328. DOI: 10.5772/53902

Hargreaves J (2006) Photosynthetic suspended-growth systems in aquaculture. *Aquaculture Engineering* **34**(3): 344–363. DOI: 10.1016/j.aquaeng.2005.08.009

McDonough W & Braungart M (2002) Cradle to Cradle. Remaking the Way, We Make Things. New York: North Point Press.

Nahar A, Abu M, Siddik B and Rahman MM (2015) Biofloc technology in aquaculture systems generates higher income in mono-sex Nile tilapia farming in Bangladesh. *Advances in Biological Research* **9**(4): 236-241.

Suneetha K & Kavitha K & Chatla D (2018) Biofloc Technology: An emerging tool for sustainable aquaculture. *International Journal of Zoology Studies*, 87-90.