Poeciliid Research

# Biofloc technology (BFT): a promising approach for the intensive production of ornamental fish

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**Abstract**. Biofloc technology (BFT) is an approach in the rearing of fish and shrimp as a means to support intensive culture, maintain optimum water quality, recycle the nutrients and reduce feed costs. The technology is primarily based on the principle of recycling nitrogenous wastes into microbial biomass that can be assimilated by the cultured animals as feeds or facilitates in maintaining good water quality. The rearing of larvae and juveniles of ornamental fish is confronted with issues on low survival rate, poor water quality and high incidence of diseases. These problems can be mitigated through the use of biofloc technology. From a number of studies reviewed, BFT offers a viable approach in ensuring sustainable production of ornamental fish. The benefits of using this technology include enhancement of water quality by reducing the levels of nitrogenous wastes, efficient feed conversion resulting in better growth and reduction in production costs and better immune response that will enable the fish to have higher resistance against infectious diseases.
**Key Words**: aquatic, BFT, nutrient recycling, water quality.

**Introduction**. The rearing of ornamental fish is an important component of the aquaculture industry, and in recent years, the ornamental fish industry is receiving a great deal of attention because of its potential to generate huge revenues. The annual global demand of ornamental fish is steadily increasing, with more than 2,000 species of ornamental fish being traded. The bulk of ornamental fish production comes from Asian countries including Singapore, Sri Lanka, Malaysia, and Thailand (Livengood & Chapman 2009; Herath & Wijewardene 2014). Most of the ornamental fish, whether freshwater or marine species, are caught from the wild and then bred in captivity. It is during the culture of ornamental fish in captivity when they are usually fed live feeds and stocked in high densities. For example, live feeds that are given to ornamental fish can be deficient in some major nutrients and can be sources of pathogens (Faizullah et al 2015). Moreover, the provision of artificial feeds in intensive culture of ornamental fish could lead to increased production of wastes, which could rapidly degrade the water quality in the rearing compartments (Poxton & Allouse 1987). These practices increase the likelihood of disease outbreaks, which could incur significant economic losses due to low productivity.

An alternative approach towards the development of intensive culture of fish is the utilization of the biofloc technology (BFT) (Avnimelech 2009; Emerenciano et al 2013). The use of this technology could improve the quality and performance of the cultured stock even at high stocking densities (Ekasari et al 2015). This technology is based on promoting bacterial growth (autotrophs and heterotrophs) from a high carbon/nitrogen (C/N) ratio in water, in order to degrade organic and inorganic wastes and control the water quality with minimal water renewal (Avnimelech 2009; Collazos-Lasso & Arias-Castellanos 2015). As a result, production of fish is increased in a sustainable way. Bioflocs are a conglomerate of algae, protozoa, rotifers, cladocerans, nematodes and other microorganisms that are aggregated in flocs and can be used "*in situ*" as a source of microbial protein by cultured organisms or they can be processed into feed ingredients (De Schryver et al 2008; Avnimelech 2009; Kuhn et al 2010). Due to the numerous benefits that BFT can bring to aquaculture, this technology can also be applicable to the rearing of ornamental fish throughout the stages of its life cycle. This review provides some updates on the use of BFT in the culture of ornamental fish. It cites the advantages of utilizing this technology on the physiology of the fish as well as in the quality of the rearing environment.

**Biofloc technology (BFT) and its effects on water quality and nutrient recycling**. BFT was first developed in the early 1970s at the Ifremer-COP (French Research Institute for Exploitation of the Sea, Oceanic Center of Pacific) using different penaeid species (Aquacop 1975). A successful commercial application of BFT is in Belize Aquaculture farm, producing approximately 11-26 tons/ha/cycle in plastic-lined grow-out ponds (Emerenciano et al 2013). In recent years, numerous large-scale shrimp farms in Asia and Central America, as well as small-scale greenhouses in USA, South Korea, and China have adopted BFT in commercial aquaculture. Furthermore, intensive research and development on BFT were conducted in several research and educational facilities, applying on key aspects such as grow-out management, nutrition, microbial ecology, biotechnology and economics (Emerenciano et al 2013).

BFT is an ecosystem management technology, whereby this approach combines both fish and heterotrophic microbial community within one water body. The heterotrophic bacteria act as the main nitrogen conversion agent, which converts nitrogenous wastes of the fish into biofloc, with minimal or no water exchange (Figure 1). This system applies the principle of assimilation of dissolved nitrogenous wastes especially ammonia, that is excreted by fish and through the breakdown of organic nitrogen coming from uneaten fish feeds. The excretion of nitrogenous metabolic wastes and their assimilation by heterotrophic bacteria result in a balance by manipulating the carbon-to-nitrogen ration (C:N ratio). This balance is attained because there is the addition of carbon sources in the water. The production of dense populations of heterotrophic bacteria results in the formation of macroaggregates known as bioflocs, which are composed of bacteria, microalgae, zooplankton, and other consortia of organic and inorganic particles (Hargreaves 2013). BFT system also favors other mechanisms depending on the environmental conditions, including nitrification (Ekasari 2014), phototrophic nitrogen uptake (Emerenciano et al 2013) and denitrification (Hu et al 2014). The biofloc is an example of protein-recycling; whereby nutrient utilization occurs when the microbes aggregate to form bioflocs, which provide constant protein source for the fish or shrimp. This allows protein utilization to increase from 15-25% in conventional aquaculture systems to 45% in BFT systems; thus, allowing a considerable reduction in feed expenditures (Avnimelech 2009). In order to facilitate the conversion of nitrogenous compounds, external carbonaceous materials such as wheat flour and molasses are added to adjust the C:N ratio in the rearing water. An optimum C:N ration stimulates good growth of heterotrophic bacteria to utilize the nitrogenous wastes, leading to the formation of biofloc (Choo et al 2015; Caipang & Avillanosa 2019). Therefore, this helps in maintaining low and non-toxic levels of ammonia, so that it does not require any large volume of water exchange. Extensive studies were carried out to determine the floc composition and nutrition, and showed that bioflocs contain more than 30% protein and a significant number of essential amino acids. Furthermore, the microbial flocs also contain vitamins and trace metals (Avnimelech 2007). Research has also demonstrated that the presence of biofloc significantly enhances the immunity and reproductive potential of fish (Avnimelech 2009).

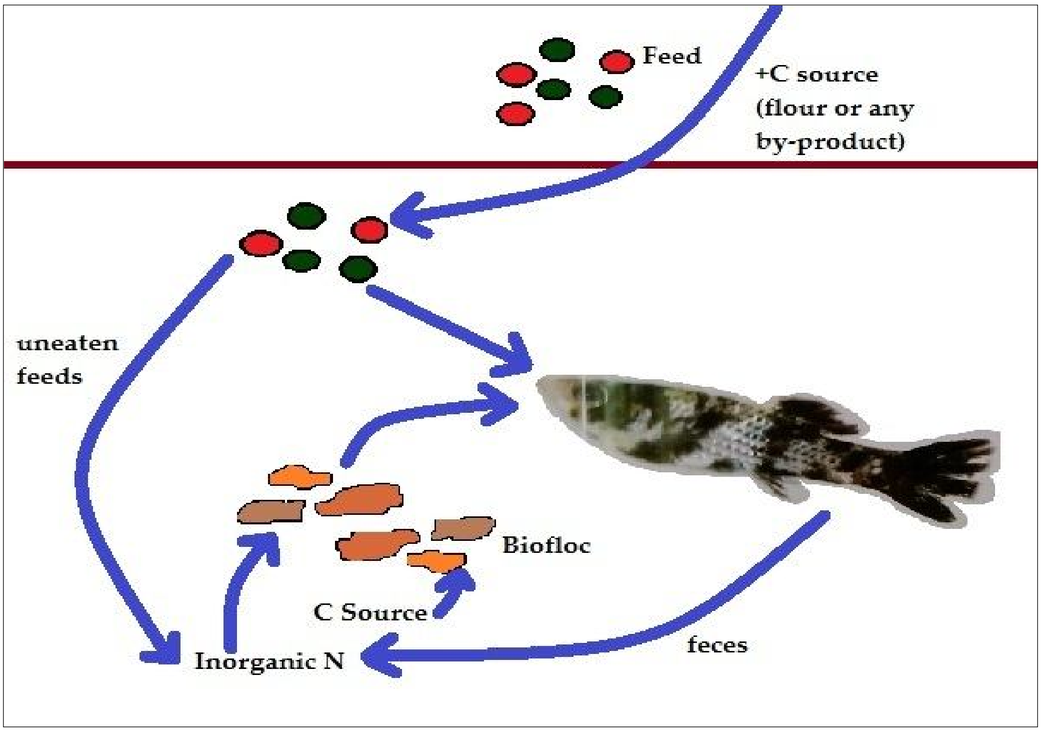


Figure 1. Mechanism of biofloc production and nutrient recycling by heterotrophic bacteria during rearing of ornamental fish (adapted from Crab et al (2012)).

**BFT and its applications in the production of ornamental fish**. The ornamental fish production is an important component of the aquaculture industry (Harini et al 2016). Nevertheless, progressing intensification of aquaculture production comes with higher production costs. Limited resources and land-spaces have also posed as obstacles in the local ornamental fish trade. Biofloc application can be a sustainable method adopted to benefit ornamental fish farming. There have been few studies done on the use of BFT in commercial ornamental fish culture in comparison with some well-established aquaculture species. In previous works done by Faizullah et al (2015) and Da Cunha (2016), demonstrated that biofloc can generate greater productivity in gold fish, *Carassius auratus* and guppy, *Poecilia reticulata*, respectively. Studies also done by Harini et al (2016) showed that blue morph cichlids, *Pseudotropheus saulosi* reared in BFT were shown to have a better survival and production rate.

Although there are numerous benefits in rearing fishes in BFT, these advantages will be negated if BFT is unable to sustain the cultures at high stocking densities. In order to minimize land usage as well as wastage of resources, ornamental fish farms have to adopt an intensive aquaculture system with high stocking densities so as to maximize profit with the least amount of production expenditures. Several studies were carried out in order to investigate the effects of stocking densities on BFT. De Lorenzo et al (2016) found that BFT is adopted for the hatchery culture of white shrimp *Litopenaeus vannamei* up to a high stocking density of 350 larvae per liter with no negative effects on production and water quality. In contrast, Liu et al (2017) showed that high density rearing of the same shrimp species in biofloc system led to impaired immune responses and lower antioxidant abilities. In addition, they also observed depressed digestive enzyme activities, despite of the probiotic effects of bioflocs. In aquaculture, Widanarni et al (2012) observed the positive influence of bioflocs in the larviculture of red tilapia, *Oreochromis* sp. Moreover, in recent studies conducted by Diatin et al (2019) and Ueno-Fukura et al (2020), demonstrated that BFT allows the increase in stocking densities of corydoras, *Corydoras aeneus* and angelfish, *Pterophyllum scalare*, respectively. Increased stocking densities of both species in BFT systems resulted in higher productivity and profitability without compromising the health and survival of the fish.

In an intensive aquaculture system, there is a high probability of fishes becoming susceptible to stress, which will lead to an increased infection vulnerability. If the diseases are severe, this may lead to a high mortality; resulting in significant economic losses. Furthermore, mitigating diseases by using antibiotics and other chemotherapeutics have been under heavy criticisms for their detrimental impacts on both the host and the environment. In light of these concerns, BFT is known to have a “natural probiotic” effects to aid in disease mitigation. Probiotics are live, dead or a component of the bacteria that act under different modes of action in conferring beneficial effects to the host or to its environment (Lazado & Caipang 2014). Bacteria that are associated with the biofloc macro-aggregates provide extra nutrients and exogenous digestive enzymes once digested by the fish and shrimp (Xu & Pan 2012), and help in the maintenance of microbial balance in the gut (Sinha et al 2008). In addition, Mansour & Esteban (2017) found that fishes reared in BFT were showed to have higher immune competency, antioxidant status and disease resistance, whereby there is a significant increase in non-specific humoral factors such as lysozyme and myeloperoxidase, as well as plasma proteins such as globulin. Another study done by Long et al (2015) also showed a significant increase in intestine amylase and liver lipase activities, as well as serum glutathione peroxidase and lysozyme activities in farmed tilapias, *Oreochromis niloticus* reared in BFT, indicating an improvement in growth, digestive enzyme activities and immune responses.

Studies showed that biofloc are also rich in bioactive compounds, such as carotenoids, chlorophylls and other phytochemicals (Ju et al 2008). The dietary carotenoids derived from ingestion of the biofloc are responsible for the red, orange and yellow colorations in fishes (Sefc et al 2014) and a study by Da Cunha et al (2020) demonstrated the positive effects on pigmentation in ornamental fish that are reared in BFT. Although little is known about the expression of carotenoid coloration in fishes, the carotenoids that are associated with bioflocs have also been reported to provide essential nutritional functions by acting as potent anti-oxidants and as immunostimulants (Xu & Pan 2013).

In a recent study done by Lim (2018) using biofloc during the culture of platy, *Xiphophorus maculatus*, he observed higher levels of nitrogenous wastes in the non-biofloc group compared with fish reared in biofloc, regardless of the stocking density. Highest ammonia, nitrite and nitrate levels were observed in the culture water of the non-biofloc groups. Significant increases in anti-protease and antioxidant activities were obtained in fishes reared in BFT. Similarly, the BFT group had the highest specific growth rate and best feed efficiency. The results clearly showed that the high-density rearing of platys in BFT did not impair growth and productivity but was able to enhance the water quality and improve the pigmentation and several immune responses of the fish. Figure 2 summarizes the benefits of using BFT in rearing ornamental fish, and these include enhancement in water quality by reducing the levels of nitrogenous wastes, efficient feed conversion and better immune response.

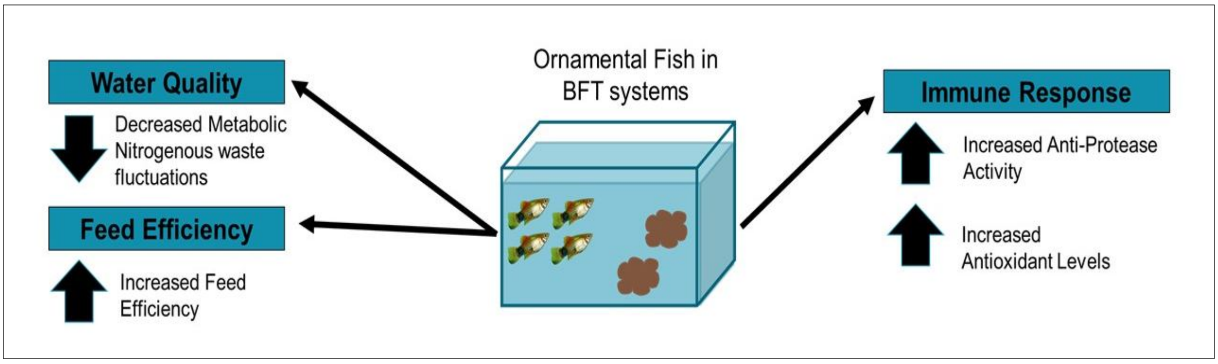


Figure 2. Benefits of using biofloc technology (BFT) in the rearing of ornamental fish.

**Conclusion and future directions**. Taken together, the results of the different studies demonstrated that BFT is a viable approach in the production of ornamental fish. Future work will focus on determining various C:N ratios that result in optimum biofloc production; thus, increasing the efficiency of this technology in producing ornamental fish. Moreover, the effects of different carbon sources on high density culture of ornamental fish can be investigated in future studies. The use of colorimetric charts or colorimeters instead of the more expensive carotenoid assays can also be explored in establishing evaluation standards of the color vibrancy in ornamental fish. Lastly, tests on poly-ß-hydroxybutyrate (PHB) production could be carried out, which is a biodegradable polymer produced by a wide diversity of microbes in bioflocs, hence allowing a better understanding of the correlations between the utilization of nitrogenous compounds and the population of heterotrophic bacteria in BFT systems.

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**Conflict of interest**. The authors declare that there is no conflict of interest.

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