Recent Advances in Aquaculture Systems Based on Microorganisms: The Biofloc Technology (Bft) Case

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Abstract

The demand for safety seafood is increasing globally year-by-year. On the other hand, the low productivity and recent diseases outbreaks lead the scientists to search for an alternative system to improve efficiently the aquaculture growth. Biofloc system, also called as biofloc technology (BFT), has the advantage to allow high production with limited or no water exchange. BFT has gained popularity because it offers a practical solution to maintain water quality and recycle feed nutrients. The continuous availability of natural food source in a form of microbial biomass lead the decrease of the feed conversion ratios and the possibility of employ alternative low protein diets, as well as alternative feed ingredients. More efforts have been done in penaeid shrimp nutrition as compared to fish nutrition under biofloc conditions.

Keywords: BFT, nutrition, microbial community, alternative ingredients

Emerenciano, M. *et al.* 2015. Recent Advances in Aquaculture Systems Based on Microorganisms: The Biofloc Technology (Bft) Case. En: Cruz-Suárez, L.E., Ricque-Marie, D., Tapia-Salazar, M., Nieto-López, M.G., Villarreal-Cavazos, D. A., Gamboa-Delgado, J., Rivas Vega, M. y Miranda Baeza, A. (Eds), Nutrición Acuícola: Investigación y Desarrollo, Universidad Autónoma de Nuevo León, San Nicolás de los Garza, Nuevo León, México, ISBN 978-607-27-0593-7,pp. 51-61.

Introduccion

The Biofloc Technology (BFT)

In recent years, studies approaching the production of fish and shrimp in biofloc system desired great attention (Avnimelech, 2015). The low productivity, recent diseases outbreaks and the increasing need of a production with an "environmental friendly" approach lead the scientists to search for an alternative system to improve efficiently the aquaculture growth. At the same time, the demand for safety seafood is increasing in a rate of ~10% per year (FAO, 2015).

According to Emerenciano *et al.* (2013), in 70's, Ifremer-COP Tahiti started R&D with enclosed limited water exchange biosecure system with different penaeid species. In connection with Aquacop and Ralston Purina, biofloc system was applied to grow-out *L. stylirostris* and *L. vannamei* both in Crystal River (USA) and Tahiti; and first considerations on benefit of such system for shrimp culture emerged. In 80's BFT was applied to grow-out tilapia and other fish species in Israel. Currently, BFT have being applied successfully in large-scale commercial farming around the world.

Biofloc system, also called as biofloc technology (BFT), has the advantage to allow the production of a great amount of fish/shrimp biomass per area with limited or no water exchange. This provides better biosecurity for the production, especially if the farm is situated in areas with high concentration of aquaculturists using the same water source. In this context, BFT has gained popularity because it offers a practical solution to maintain water quality and recycle feed nutrients simultaneously (Xu and Pan, 2012). BFT has become a popular nursery and grow-out technology, although interest in larviculture and husbandry is increasing day-by-day.

Other advantage of the biofloc system is the possibility to use alternatives low protein diets and consequently decrease the production costs (Ballester *et al.*, 2010; Scopel *et al.*, 2011); mainly due to the continuous availability of natural food source in a form of bacteria, protozoa, nematodes, microalgae, rotifers and copepods (Azim and Little, 2008; Ray *et al*., 2010). Although a diverse microbial community is present in BFT, many factors could modify the microorganism profile in the cultured ambience such as the C:N ratio, total organic load, source of organic carbon, water exchange ratio (minimum or zero), mix intensity in the water column and light intensity. Water quality parameters such as total suspended solids, temperature, salinity, dissolved oxygen and pH also could affect the microbial community (Martínez-Córdoba *et al* 2014).

BFT and Nutrition

Some components in aquafeed are focus of intensive research mainly due to its effects on improvement of animal growth, health and also aiming to decrease the production costs. Fishmeal is one of the most expensive and unsustainable ingredient used in aquaculture diets (Naylor *et al*., 2009). Therefore, the replacement or reduction of fishmeal presents a great interest for the aquaculture industry. On the other hand, fishmeal posses an excellent digestibility and amino acids profile (Cruz-Suárez *et al*., 2007). Problems related to the fishmeal replacement by alternative ingredients such as deficiency of some essential amino acids, presence of anti-nutritional factors, palatability and digestibility have been identify (Forster *et al*., 2003; Naylor *et al*., 2009).

Although problems exist, many cases of success have been reported replacing fishmeal by alternative protein sources such as vegetable grains and terrestrial animal industry by-products. In the specific case of penaeid shrimp, Forster *et al*. (2003) and Suarez *et al*. (2009) recommended levels until 75% and 80% of fishmeal replacement using cattle by-product and a mixture of canola and soya, respectively. Amaya *et al*., (2007) and Hernández *et al*., (2008) concluded that is possible to replace 16% and 35% of fishmeal by poultry and swine by-product, respectively, without shrimp performance losses. Samocha *et al*. (2004) and Cruz-Suárez *et al*., (2007) achieved success replacing 100% and 80% of fishmeal by soya meal and poultry by-product in *L. vannamei* diets. Paripatananont *et al*., (2001) achieved 50% of replacement using soya protein concentrate in *Penaeus monodon*

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diets.

In the nutrition of animals in BFT, microorganism present in the system might help by three ways: i) reducing commercial feed ingestion by microbial biomass consumption and lead the decrease of the feed conversion ratios (Wasielesky *et al.,* 2006); ii) employment of alternative low protein content diets (Ballester *et al*., 2010) and iii) reduce or replace fishmeal by alternative feed ingredients (Scopel *et al* 2011). It is important to note that in systems with natural productivity (i.e. semi-intensive pond systems) natural biota plays a key role. For instance, it has been estimated that only 29.7% of the carbon and 33.8% of the nitrogen comes from the inert feed in penaeid culture (Nunes *et al*., 1997; Miranda *et al*., 2009). In water column, biofloc available 24 hours per day can be utilized for fingerlings (Ekasari *et al.,* 2015), shrimp larvae (Lorenzo *et al.*, 2015) and postlarvae (Mishra *et al* 2008; Emerenciano *et al.*, 2011 and 2012a), juveniles (Wasielesky *et al.*, 2006; Azim and Litle 2008) and for the first stages of broodstock's gonads formation and ovary development (Emerenciano *et al.*, 2013).

The microorganisms present in BFT could be a rich source of native protein and amino acids for aquacultural organisms (Ballester *et al.*, 2010). The concept of "native protein" is related to protein source without previous treatment mainly including live food (Emerenciano *et al*., 2012b). Also, the microbial community is a continuously source of lipids (Maicá *et al*., 2012), vitamins and essential aminoacids (Ju *et al*., 2008). Rojas-López, 2015 evaluated the aminoacid profile of tilapia (*Oreochromis niloticus* x *Oreochromis mossambicus*), cultured in BFT with four experimental diets (fishmeal replacement by vegetable meals); in the diet with total replacement found, that lisina, an aminoacid limiting in the vegetal meals, appear in the tilapia tissue profile in similar concentration that commercial diet, as a contribution of the microbial biomass (Table 1). According to Emerenciano *et al*.,(2013), protein, lipid and ash content in biofloc particles could vary substantially (12 to 49, 0.5 to 12.5 and 13 to 46%, respectively). The same trend occurs with fatty acids (FA) profile. Essential FA such as linoleic acid (C18:2 n-6 or LA), linolenic acid (C18:3 n-3 or ALA), arachidonic acid (C20:4 n-6 or ARA), eicosapentanoic

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acid (C20:5 n-3 or EPA) and docosahexaenoic acid (C22:6 n-3 or DHA), as well as sum of n-3 and sum of n-6 differ considerably between 1.5 to 28.2, 0.04 to 3.3, 0.06 to 3.55, 0.05 to 0.5, 0.05 to 0.77, 0.4 to 4.4 and 2.0 to 27.0% of total FA, respectively.

For broodstock, BFT can enhance the shrimp reproductive performance as compared to the conventional pond and tank-reared systems. Moreover, fresh food items (i.e. squid, mussels, polychaetes, artemia biomass, etc.) combined with BFT helped to improve reproductive performance in terms of shorter latency period, higher spawning activity and higher number of eggs per spawn (Emerenciano *et al* 2012b and 2013b). In tilapia broodstock, Ekasari *et al.*, (2015) evaluating *Oreochromis niloticus* breeders (85±5 g) suggested that the application of BFT effectively enhanced reproductive performance and therefore *in situ* biofloc production can be suggested as a way to increase tilapia seed production. In addition, previous promising results also have been showed over-wintering tilapia in BFT (Crab *et al* 2009). In *Macrobrachium rosenbergii*, Perez-Fuentes *et al*.,(2013) evaluated during six months two rearing systems: biofloc and traditional water-exchange cultivation. The results suggested that survival rate was similar in both treatments (>85%), but final size was significantly higher in BFT. Protein (51.19%) and lipid (13.84%) content in harvested prawns was also higher in BFT. With this result in mind, BFT seems to be an efficient tool for *M. rosenbergii* broodstock production and maintenance.

Table 1. Amino acid profile (g/100 protein) of tilapia tissue (*Oreochromis mossambicus* x *Oreochromis niloticus*) cultured with different diets in BFT (C = commercial diet, 0, 10, 20 and 30 = experimental diet containing 0%, 10%, 20% and 30% of fishmeal, respectively). Different letters in the same row indicate significant differences (P<0.05); modified from Rojas-Lopez (2015).

Amino acid	C	0%	10%	20%	30%
Isoleucine	2.58 ± 0.47^{bc}	3.52 ± 0.70^{abc}	4.54 ± 0.48^{a}	4.41 ± 0.21^{ab}	2.02 ± 0.45^{c}
Leucine	7.53 ± 2.38^{a}	5.58 ± 0.25^{a}	7.27 ± 1.57^{a}	8.03 ± 0.23^{a}	4.09 ± 0.03^{b}
Lysine	5.24 ± 0.59^{ab}	9.10 ± 2.23^{a}	7.42 ± 1.14^{ab}	8.20 ± 0.77^{ab}	4.18 ± 0.35^{b}

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Methionine	7.71±4.40[a]	2.40±0.26[b]	2.35±0.26[b]	2.05±0.22[b]	1.73±0.22[b]
Phenylalanine	1.61±0.46[a]	2.28±0.48[a]	2.76±0.51[a]	2.89±0.16[a]	1.52±0.04[a]
Threonine	1.51±0.21[bc]	1.95±0.15[ab]	2.17±0.18[a]	1.41±0.13[bc]	0.98±0.12[c]
Tryptophan	12.41±5.48[a]	2.84±0.49[b]	2.78±0.57[b]	2.70±0.13[b]	1.23±0.09[c]
Valine	3.25±0.57[b]	6.17±0.91[a]	5.37±0.71[ab]	5.27±0.19[ab]	3.79±0.30[ab]
Histidine	12.01±5.37[a]	2.25±0.20[b]	2.40±0.29[b]	2.46±0.50a[b]	1.24±0.01[b]

Regarding to nutrition of juveniles, Scopel *et al*. (2011) evaluating the replacement of fishmeal (0, 12.5 and 21.0%) by a combination of soya and animal terrestrial by-products in BFT found that 12.5% of replacement did not affect shrimp growth. Recently, Camaño (2014) indicated that fishmeal and fish oil could replaced by vegetable sources at a level of 75% without growth losses in BFT systems. Bauer *et al*. (2012) suggested that a mixture of soy protein concentrate and microbial floc meal can be utilized as a substitute for fishmeal in diets for *L. vannamei* juveniles. Microbial floc meal can be generated in bioreactors (Kuhn *et al* 2009) or removing the excess of solids from culture tanks or ponds by the use of settling devices (Ray *et al* 2010).

It is also important to note that bacteria protein-source plays an important role in the equilibrium and re-ingestion of particulate organic matter and faeces (coprophagia) left by shrimp results in a form of constant food supply. The colonization of shrimp gut by bacteria had been shown positive effects such as improvement of immune system (Kim *et al* 2014), digestive enzymes activity and increasing the availability of extracellular enzymes (Xu & Pan, 2012) acting as "natural probiotic" (De Schryver *et al*., 2012).

In biofloc culture system, there are several types of bacteria, the most important in the system stability are heterotrophic, nitrifying and cyanobacteria. Heterotrophic bacteria are those using organic compounds as a carbon source, under appropriate conditions (temperature and carbon source) have rapid growth. This group of bacteria consume organic matter and convert waste into bacterial biomass with high nutritional value. Huerta-Rábago (2013) found a positive correlation among total suspended solids and heterotrophic bacteria (Figure 1) in a tilapia culture, in the same study, the ammonia oxidizer bacteria have a positive correlation with a heterotopic bacteria (Figure 2).

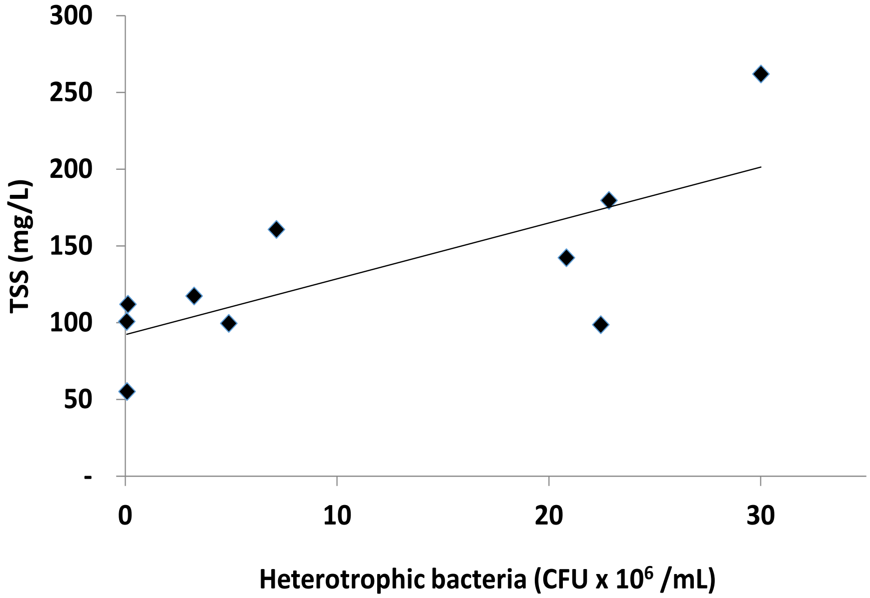

Figure 1. Relationship of total suspended solids and colony forming units of heterotrophic bacteria in a BFT Tilapia (*Oreochromis niloticus*) culture (r = 0.73), Huerta-Rábago (2014).

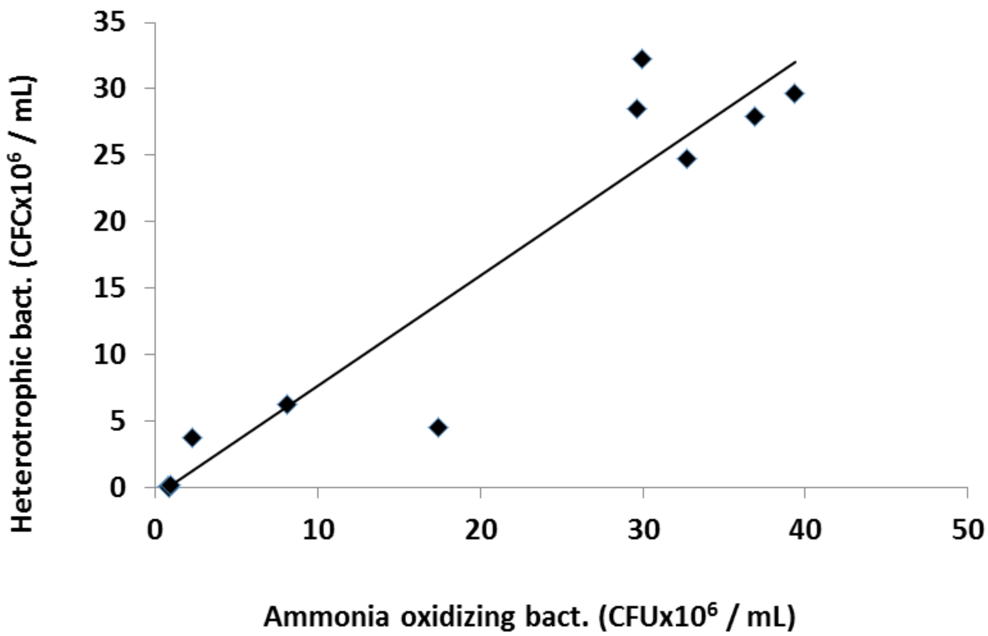

Figure 2. Relationship of colony forming units of heterotrophic and ammonia oxidizing bacteria in a BFT Tilapia (*Oreochromis niloticus*) culture (r = 0.90), Huerta-Rábago (2014).

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Final considerations

The microorganisms in general play an important role in aquatic environments. There are wide ranges of opportunities to manage aquacultural systems in order to promote microbial growth that may have the major benefits for the farmed species. As the biosecurity is a priority in aquaculture industry, biofloc technology (BFT) are up today one of the most biosecure system used around the world with multiple and successful experiences. Moreover, microorganisms in BFT might partially replace commercial feed, protein content in diets or decrease its dependence of fishmeal. Biofloc technology will enable aquaculture grow towards an environmental friendly approach.

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