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Review

Biofloc technology in aquaculture: Beneficial effects and future challenges

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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. 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 the beneficial effects of the technology and identify some challenges for future research.

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1. Introduction

With almost seven billion people on earth, the demand for aquatic food carries on to increase and hence, expansion and intensification of aquaculture production are highly required. The prime goal of aquaculture expansion must be to produce more aquaculture products without significantly increasing the usage of the basic natural resources of water and land (Avnimelech, 2009). The second goal is to develop sustainable aquaculture systems that will not damage the environment (Naylor et al., 2000). The third goal is to build up systems providing an equitable cost/benefit ratio to support economic and social sustainability (Avnimelech, 2009). All these three prerequisites for sustainable aquaculture development can be met by biofloc technology.

2. Biofloc technology

If carbon and nitrogen are well balanced in the solution, ammonium in addition to organic nitrogenous waste will be converted into bacterial biomass (Schneider et al., 2005). By adding carbohydrates to the pond, heterotrophic bacterial growth is stimulated and nitrogen uptake through the production of microbial proteins takes place (Avnimelech, 1999). Biofloc technology 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 (Fig. 1). This promoted nitrogen uptake by bacterial growth decreases the ammonium concentration more rapidly than nitrification (Hargreaves, 2006). Immobilization of ammonium by

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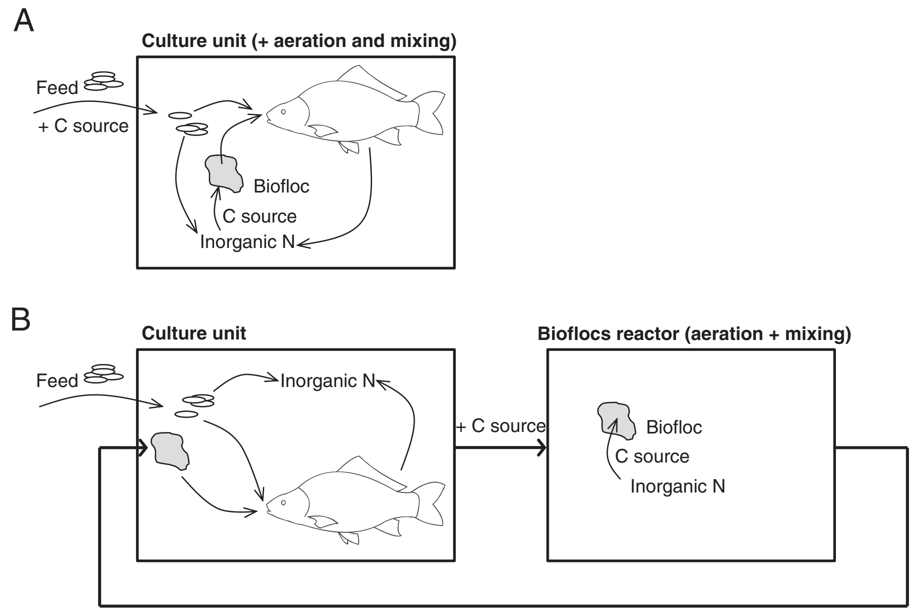

Fig. 1. Schematic representation of how bioflocs can be implemented in aquaculture systems. (A) Integration of bioflocs within the culture unit by using feed with a relatively low N content and/or the addition of a carbon source. The bioflocs consume inorganic N waste together with the carbon source, thereby producing microbial biomass that can be used as a feed by the animals. (B) Use of a separate bioflocs reactor. The waste water from the culture tank is brought into the biofloc reactor, where a carbon source is added in order to stimulate biofloc growth. The water of the biofloc reactor can be recirculated into the culture tank and/or bioflocs can be harvested and used as a supplementary feed.

heterotrophic bacteria occurs much more rapidly because the growth rate and microbial biomass yield per unit substrate of heterotrophs are a factor 10 higher than that of nitrifying bacteria (Hargreaves, 2006). The microbial biomass yield per unit substrate of heterotrophic bacteria is about 0.5 g biomass C/g substrate C used (Eding et al., 2006). A schematic calculation of the amount of carbon needed for biofloc growth is presented in Fig. 2.

Suspended growth in ponds consists of phytoplankton, bacteria, aggregates of living and dead particulate organic matter, and grazers of the bacteria (Hargreaves, 2006). Typical flocs are irregular by shape, have a broad distribution of particle size, are fine, easily compressible, highly porous (up to more than 99% porosity) and are permeable to fluids (Chu and Lee, 2004). Avnimelech (2009) recently published the handbook 'Biofloc Technology — A practical guide book' that is directed to aquaculturists, farmers, students and scientists and is a first tremendous step forward in providing general information on this technology. We refer readers to this book and to our previous

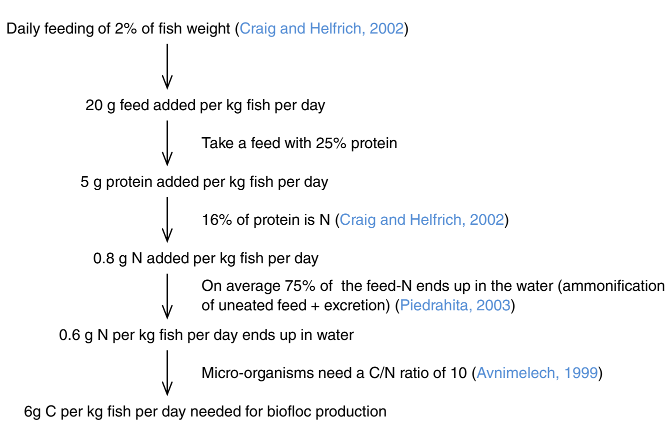

Fig. 2. Schematic calculation of the daily amount of carbon needed to remove the nitrogen wasted from uneaten feed and excretion from the animals by bioflocs. The amount of carbon source added will then depend on the carbon content of the carbon source. In case of acetate or glycerol (both containing 0.4 g C per g), 15 g of carbon source would be needed per kg fish per day. The assumption that 75% of the feed-N ends up in the water is based on Piedrahita (2003).

paper on the basics of biofloc technology (De Schryver et al., 2008) for detailed information on the use of biofloc technology in aquaculture. The current review aims to highlight the strengths of the technology and identify challenges for further research (Box 1).

3. The strengths of biofloc technology

Box 1
Challenges for further research.

- Selection and positioning of aerators.
- Integration in existing systems (*e.g.* raceways, polyculture systems).
- Identification of micro-organisms yielding bioflocs with beneficial characteristics (nutritional quality, biocontrol effects) to be used as inoculum for biofloc systems.
- Development of monitoring techniques for floc characteristics and floc composition.
- Optimalization of the nutritional quality (amino acid composition, fatty acid composition, vitamin content).
- Determination of the impact of the carbon source type on biofloc characteristics.

Biofloc technology makes it possible to minimize water exchange and water usage in aquaculture systems through maintaining adequate water quality within the culture unit, while producing low cost bioflocs rich in protein, which in turn can serve as a feed for aquatic organisms (Crab, 2010; Crab et al., 2007, 2009, 2010a). 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