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Feeding with microbial flocs by tilapia in minimal discharge bio-flocs technology ponds

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Abstract

The uptake of microbial flocs by tilapia was evaluated. Fish (tilapia Mozambique, 107 g) were stocked in 1 m^3 tanks filled with water from a limited exchange intensive tilapia producing pond (bio-floc technology, BFT system). Tagged ammonium nitrogen ($^{15}NH_4(SO_4)_2$) and starch to ensure incorporation of the ^{15}N into the bio-flocs, were added. Fish were held in the tanks for ca 2 weeks, not fed during a week period, when the only source of feed was microbial flocs. Floc volume, total suspended solids, as well as total carbon and nitrogen in suspension were monitored.

The floc plug in settling cones contained 1.4% as dry matter.

Feed uptake, evaluated through the decrease with time in respect to 4 independently determined parameters, namely floc volume, TSS, C and N in suspension, was found to be 10.3±1.0 g kg $fish^{-1}$ day^{-1}, averaged for the computed values for these parameters However, this preliminary evaluation was based on the assumption that fish harvesting is the only mechanism affecting bio-flocs mass, neglecting biodegradation and production of flocs. Gross daily uptake of nitrogen as determined using ^{15}N uptake data was 0.25 gN kg^{-1} (1.6 g protein), equivalent to the daily uptake of 6.2 g kg^{-1} of dry bio-flocs, 60% of that computed by the simplified mass balance approach. This difference may be attributed to microbial degradation of the bio-flocs.

Even the lower flux as evaluated through ^{15}N uptake, constituted, in the specific case studied, almost 50% of conventional feed ration.

Keywords: Microbial control; Intensive ponds; ^{15}N uptake; Flocs; Bio-flocs technology

1. Introduction

Intensive aquaculture systems are used to efficiently produce dense biomasses of fish or shrimp. An intrinsic feature of these systems is the rapid accumulation of feed residues, organic matter and toxic inorganic nitrogen species. This cannot be avoided, since fish retain only 20–30% of feed nutrients (e.g. Avnimelech and Lacher, 1979; Avnimelech and Ritvo, 2003; Boyd, 1985). The rest is excreted and typically accumulates in the water. As a result, intensive aquaculture industry faces two major problems. The first is the water quality deterioration caused by the high concentrations of metabolites and the second is the low feed utilization in cases when high water exchange, within or outside the pond system, is practiced.

The principles of growing fish or shrimp in limited water exchange intensive ponds were developed simultaneously for shrimp in the Waddel Mariculture Center in the USA and for fish, mostly tilapia, in Israel (Avnimelech et al., 1989; Avnimelech et al., 1994; Hopkins et al., 1993; Chamberlain and Hopkins, 1994) and practiced in the

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USA (Serfling, 2000), in the beginning of the 1990's. Biofloc technology, BFT, (called also active suspension ponds, heterotrophic ponds, green soup and other terms) was first developed to solve water quality problems. Water quality management is based upon developing and controlling dense heterotrophic bacteria within the culture component. This goes in tandem with zero or minimal water exchange rate. A microbial community develops, reaching a density in the order of 10^7 colonies forming units, CFU, ml^{-1} (Burford et al., 2003), forming bio-flocs that contain bacteria, other micro-organisms, protozoa and zooplankton.

Accumulation of toxic inorganic nitrogen species (NH_4, NO_2) is prevented in bio-flocs system by maintaining a high C/N ratio and inducing the uptake of ammonium by the microbial community (Avnimelech et al., 1994; McIntosh, 2000). This process was quantitatively formulated (Avnimelech, 1999), verified and practiced by farmers world-wide (Browdy et al., 2001; Panjaitan, 2004).

A by-product of this is the growth of the microbial community and the production of microbial protein. Harvesting of the bio-flocs by fish serves as an addition of high value feed, recycling of the non-utilized fraction of the feed and was shown to double the utilization of protein and feed by fish or shrimp (Avnimelech et al., 1989; McIntosh, 2000; Velasco et al., 1998).

The fast spread and the large number of BFT shrimp farms induced significant research effort of processes in BFT shrimp production systems (e.g Browdy et al., 2001; Burford et al., 2003; Taw, 2005). Yet, practically no work was done in BFT fish production units. The biomass in fish producing BFT is in the range of 10–40 kg m^{-3}, as compared to a range of 1–2 kg m^{-3} for shrimp. It is expected that process rates and concentrations in the fish ponds will be higher than in shrimp ponds and easier to evaluate. Thus, besides its importance for fish culture, research in such ponds can reveal processes that are more difficult to evaluate in shrimp ponds.

It is clear that bacteria, metabolizing carbohydrates, take up dissolved inorganic nitrogen (mostly NH_4) and produce protein. Microbial flocs of different sizes can be taken up by fish or shrimp and serve as a feed source (Avnimelech et al., 1989; Burford et al., 2004; Tacon et al., 2002) However, a quantitative and predictive study of this is very complicated. A number of processes are taking place simultaneously, formulated schematically as:

$$d[BF]/dt = BF_{production} - (BF_{harvesting} + BF_{degradation}) \quad (1)$$

Where $d[BF]/dt$ is the bio-flocs concentration change with time, as affected by production, harvesting by fish and biodegradation. Each of the processes given in Eq. (1) is complex and depends on a variety of factors:

a. Production of bio-flocs depends on the supply of organic substrates to the microbial community, both external sources (feed supply, algal activity) or by the excretion of un-utilized feed components by fish. In addition bio-flocs production most probably depends on the quality of the added substrates, its C/N ratio, bio-availability and other factors.
b. Uptake of the bio-flocs by fish depends most probably on the fish species and feeding traits, fish size, floc size and floc density. It is possible that bio-flocs harvesting depends also on the presence and rate of formulated feed added to the pond. In addition, feed eaten by the fish may be utilized and accumulate in the fish, or excreted and serve as a substrate for the production of more bio-flocs.
c. Biodegradation of the floc depends on the microbial community associated with the bio-flocs, be it bacteria, protozoa or others.
d. Finally, all of these processes may be affected by environmental and operational conditions such as temperature, water salinity, water exchange rate (affecting floc mean residence time, FMRT), mixing intensity and many other.

The study of this complex system is difficult, since it is practically impossible to study all factors simultaneously and since the monitoring of any of the processes given in Eq. (1) is technically difficult. We consider this work as a preliminary work aimed at the development of methodology and conceptual approach toward the quantitative evaluation of bio-flocs technology.

The goal of this work was to reveal some of the processes involved in the bio-floc system, to get some quantitative data on harvest of flocs by tilapia and to evaluate some methods that can be used in future research and monitoring. This work is based, on one hand, upon the evaluation of the material balance of suspended components along a two weeks experimental period. The second approach was to evaluate nutrients uptake from flocs through the evaluation of ^{15}N tagging of the flocs and its uptake by fish. The ^{15}N uptake was used as a means to evaluate the contribution of microbial protein to the nutrition of shrimp by Parker and Anderson (1989), Cam et al. (1991) and Burford et al. (2004). Avnimelech et al.