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Performance of a temperate-zone channel catfish biofloc technology production system during winter

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ABSTRACT

Channel catfish (*Ictalurus punctatus*) have been grown successfully in an outdoor biofloc technology production system. Outdoor biofloc production systems in the tropics are operated year-round, whereas the channel catfish studies were conducted only during the growing season and biofloc production tanks were harvested and idled for the winter. If an outdoor biofloc production system is to be adopted by farmers at temperate latitudes, then data gaps related to system and fish performance over the winter must be addressed. The present study was conducted to address these data gaps for channel catfish culture. Waters from a recently completed biofloc production experiment that contained low (153.3 mg/L) and high (790.0 mg/L) total suspended solids were retained for this study. Three 15.7-m^3 tanks per water type each were stocked (8 kg/m^3) with market size channel catfish from that same study for a 152-day study from November to April. Mean chlorophyll *a* concentrations were similar in both treatments during the first 55 days, after which treatments diverged and chlorophyll *a* concentration increased linearly ($P < 0.001$, $R^2 = 0.721$) to a mean final concentration of 2251.7 mg/m^3 in the low solids treatment. Ammonia from ammonium chloride spikes (1.25–1.5 mg TAN) added on three occasions during the experiment was biotransformed completely, putatively by algal uptake and nitrification. Ammonia biotransformation rate was linearly related to mean water temperature in the high solids ($P < 0.001$, $R^2 = 0.920$) and low solids ($P = 0.002$, $R^2 = 0.761$) treatments. Catfish survival through the winter was high (99.75%) in biofloc tanks and did not differ significantly between treatments. Net fish yield did not differ significantly between treatments. However, net fish yields were 1–4% less than initial fish biomasses. Water in the biofloc production tanks appeared to retain through the winter the ability to biotransform ammonia regardless of whether phytoplankton or suspended solids predominate and despite sustained input of ammonia-nitrogen. Having an active biofloc in the spring obviates the start-up time required to establish a new, fully functional biofloc and the associated TAN and nitrite spikes.

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1. Introduction

The biofloc technology (BFT) production system results in high yields of aquatic animals because two important production-limiting factors, dissolved oxygen and total ammonia-nitrogen concentrations, are maintained at near-optimal levels despite high stocking and feeding rates (Avnimelech, 1999; Burford et al., 2004; Hargreaves, 2006). High dissolved oxygen concentration is maintained by continuous aeration, which also maintains the biofloc suspended in the water column. The biofloc is a complex of living organisms closely associated with particulate organic matter. Nitrogenous waste excreted by the intensively fed culture animals utilized by phytoplankton and bacteria, which are part of this complex of living organisms.

Stocker-size and market-size channel catfish (*Ictalurus punctatus*) were grown successfully in an outdoor BFT production system and a net yield as high as 9.3 kg/m^3 was reported (Green, 2010; Schrader et al., 2011; Green et al., 2014). Unlike outdoor BFT production systems in the tropics that are operated year-round, the channel catfish studies were conducted only during the temperate-zone growing season and BFT production tanks were drained and idled at harvest. Operating the BFT system only during the growing season implies that at harvest the fish must be marketable or of a size appropriate for a subsequent stage of grow out. Otherwise, fish will be moved unnecessarily. Additionally, 4–6 weeks are required at spring start-up for a fully functional biofloc to develop.

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If an outdoor BFT production system is to be adopted by farmers at temperate latitudes, then data gaps related to system and fish performance over the winter must be addressed.

Pond production of channel catfish requires that fish be over-wintered at least once before being harvested as food fish. Survival of fish to harvest is good and generally exceeds 75% (Robinson and Li, 2008; Li et al., 2009). Recommendations for winter feeding of channel catfish vary feeding rates based on threshold water temperatures (Robinson et al., 2001). Gains or losses in individual fish weight and net yield can depend on the winter feeding strategy used, and fish size and survival (Lovell and Sirikul, 1974; Tackett et al., 1987; Tidwell and Mims, 1991; Burtle and Newton, 1993; Nanninga et al., 2011; Bastola et al., 2012).

The waters used for this experiment were retained from a just-completed freshwater BFT experiment that evaluated different levels of solids control; retained waters had high or low total suspended solids (TSS) concentrations. High TSS concentration in BFT can affect negatively culture animal performance and removal of solids to 200–400 mg/L TSS is recommended (Ray et al., 2010; Green et al., 2014). Furthermore, the retained waters used in the present experiment themselves will be retained for a follow-on study to evaluate re-use of BFT water during a second growing season. The objectives of the present experiment were to quantify changes in water quality and ammonia biotransformation capacity and channel catfish performance throughout the winter.

2. Materials and methods

2.1. Biofloc technology production system

Six wood-framed rectangular tanks with a slightly sloped bottom tanks (18.6 m^2, mean 15.7 m^3 of water, mean depth of 0.81 m) lined with high density polyethylene (HDPE) located outdoors at the USDA Agricultural Research Service (ARS), Harry K. Dupree Stuttgart National Aquaculture Research Center (HKD-SNARC), Stuttgart, AR, USA, were used for this study. One 2.6-kW blower per three tanks provided air (ca. 295 m^3/h) continuously through a diffuser grid (six 5.95 m × 2.5 cm polyvinyl chloride pipes with 1.9-mm diameter holes drilled at 15-cm intervals) on the bottom of each tank. Waters from a BFT production experiment testing different levels of solids removal that concluded 14–15 November 2013 and contained low (153.3 ± 39.5 mg/L, mean ± SE) or high (790.0 ± 48.4 mg/L) TSS were retained for this study. Each tank required about 10% well water to complete filling. Triplicate tanks each were assigned randomly to the low and high TSS concentrations. Solids were not removed from tanks during this study.

2.2. Water quality

Initial water samples for this study were collected and analyzed 6 days after stocking. Water samples were collected from each tank on average at 2 week intervals at approximately 0830 h. Total ammonia-nitrogen (TAN) was analyzed fluorometrically using the *o*-phthaldialdehyde method in a flow injection system (Genfa and Dasgupta, 1989). Nitrite-nitrogen (NO_2-N, diazotization), nitrate-nitrogen (NO_3-N, cadmium reduction), and soluble reactive phosphorus (ascorbic acid method) were analyzed using flow injection analysis according to manufacturer instructions (FIAlab 2500; FIAlab Instruments, Bellevue, Washington). Total alkalinity and total suspended solids were measured using the methods of Eaton et al. (2005). Chlorophyll *a* was extracted in 2:1 chloroform:methanol from phytoplankton (for this study, "phytoplankton" includes planktonic algae and cyanobacteria as well as those attached to bioflocs) previously filtered from water samples by using a 0.45-μm pore size glass fiber filter, and the chlorophyll *a* concentration in the extract was determined by spectroscopy (Lloyd and Tucker, 1988). Sample pH was measured electrometrically.

Dissolved oxygen (DO) concentration and water temperature in each tank were monitored continuously by a galvanic oxygen sensor (Type III, Oxyguard, Birkerød, Denmark) and a thermistor (Model 109, Campbell Scientific, Logan, Utah) connected to a datalogger (Model CR206 or CR10X, Campbell Scientific, Logan, Utah). Air temperature data was obtained from the weather station located within 0.5 km at USDA ARS Dale Bumpers National Rice Research Center, Stuttgart, Arkansas.

Stock salt (144 g/m^3) was added to each tank to ensure chloride concentration exceeded 100 mg/L. Sodium bicarbonate (72 g/m^3) was added once (day 123) only to high solids treatment tanks to maintain pH values between 7.0 and 7.8 and total alkalinity about 100 mg/L as $CaCO_3$.

2.3. Ammonium chloride additions

Ammonium chloride (untreated technical grade, 99.9%, The Dallas Group of America, Whitehouse, New Jersey) was added to each tank on three occasions to measure TAN biotransformation over time. Dry matter content of ammonium chloride was 99.6%. Each tank was dosed with ammonium chloride, on a dry matter basis, to add 1.5 mg/L TAN (16 December 2013), and 1.25 mg/L TAN (27 January 2014; 10 March 2014). The quantity of TAN added was high enough to be detectable, but unlikely to be detrimental to the catfish (Hargreaves and Kucuk, 2001). Water samples were collected from each tank at 0 min, 15–60 min, 4 h (10 March only), 7–8 h, 24 h, 48 h, 72 h, 96 h, and 173 h (27 January 2014 only) after TAN addition and analyzed for TAN and NO_2-N; samples were analyzed for NO_3-N at the beginning and end of each spike event.

2.4. Catfish stocking, feeding, and harvesting

Channel catfish (*I. punctatus*) harvested from the BFT production experiment were re-stocked into tanks. Mean biomass at stocking was 7.8 ± 0.2 and 8.2 ± 0.5 kg/m^3 for the low and high solids treatments, respectively, and did not differ significantly between treatments (P = 0.490). Mean initial weight did not differ significantly between treatments and averaged 560.8 ± 5.8 and 611.3 ± 22.9 g/fish for the low and high solids treatments, respectively. Fish in each tank were fed as much 32% protein feed (Delta Western Feed Mill, Indianola, Mississippi) as they could consume in 10 min once the afternoon water temperature exceeded 16 °C for two consecutive days, and the quantity recorded. Fish were harvested from all tanks on 16 April 2014, 152 days after stocking. At harvest, 25% of fish in each tank were weighed individually and the remainder were counted and weighed in bulk. Animal care and experimental protocols were approved by the HKDSNARC Institutional Animal Care and Use Committee and conformed to ARS Policies and Procedures 130.4 and 635.1.

2.5. Data analysis

Data were analyzed by mixed models analysis of variance (MIXED) and linear regression (REG) procedures in SAS v. 9.3. Initial TSS concentration was the fixed effect. The repeated measures mixed models procedure (MIXED) was used to compare slopes of ammonia-nitrogen transformation over time between treatments for each spike event; first-order ante dependence covariance structure was used for the first two spike events, and spatial power covariance structure was used for the third spike event (Littell et al., 2006).