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Efficiency of biofloc system on the growth and survival of African catfish (*Clarias gariepinus*) fingerlings

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Abstract

Scarcity of water remains a major restriction to fish culture operations in inland aquaculture. The present study reduced water usage in the larval rearing of African catfish (*Clarias gariepinus*) by application of biofloc technology (BFT). A 60-day growth trial was conducted to evaluate the growth and survival of African catfish (*C. gariepinus*) fingerlings in biofloc culture system supplemented with different carbohydrates (molasses, rice bran, cornstarch). Complete randomized design was used with four treatments replicated four times. BFT-based culture significantly increased survival (96-98%), weight gain (1101-1156%), specific growth rate (1.81- 1.83) of *C. gariepinus*, compared to the control or conventional culture system: 77%, 551%, 1.33 respectively ($p<0.05$). Lower feed conversion ratio was observed in BFT treated fish (1.25- 1.30) compared to control (1.36). BFT significantly reduced total ammonia nitrogen (TAN) while increasing total suspended solids (TSS). Biofloc culture supplemented with rice bran, molasses and cornstarch enhanced the growth and survival of *C. gariepinus* fingerlings while lowering TAN (0.13 -0.15 ppm) and increasing TSS (146- 506 ppm). Results suggest that biofloc system improved nutritional composition contributing to enhanced growth and survival rate of African catfish (*C. gariepinus*) fingerlings.

Keywords - African catfish, biofloc technology, carbohydrate source, total ammonia nitrogen, total suspended solids

Introduction

Water supply is vital in inland fisheries to support intensive production. However, recent climatic conditions on weather fluctuations such as prolonged drought seasons may affect the quantity of water distribution from tributaries which in turn cause shortage in water change requirement during larval rearing culture. Intensification of culture also means requiring sufficient quantity of water to support water requirement during the culture period. To address this problem, studies have opted for intensive production system which utilizes water recycling principles such as recirculating aquaculture system, raceway system, and activated suspension culture system which later referred to as biofloc culture system.

Biofloc technology (BFT) is an aquaculture practice based on zero-water exchange in the duration of the culture period. The principle is based on the balancing mechanism of carbon and nitrogen components through the addition of carbohydrate source (Hargreaves, 2006; Avnimelech and Kochba, 2009; Crab et al., 2010). Supplementation of carbohydrate source creates a mechanism of recycling fish culture by-products and converts it into food source for the cultured organism (De Schryver et al., 2008; Crab et al., 2012). In BFT system, the balance between carbon and nitrogen stimulates the growth of a microbial community composed of heterotrophic community which enhances natural productivity, water quality and nutrient cycling (Azim & Little, 2008). The heterotrophic community is measured via total suspended solids (TSS) in the culture tank. This mechanism allows nitrogen uptake by heterotrophic bacterial growth while decreasing the ammonium concentration (Hargreaves, 2006) thus reducing toxicity of waste in the tank. Common indices of ammonium concentration in a culture tank is measured via total ammonium nitrogen (TAN) or ammonia test. The conversion of nitrogen-

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waste into food was cited to contribute a positive relation to the growth performance of cultured organisms in biofloc system (Hargreaves, 2006; Avnimelech, 2007; Avnimelech & Kochba, 2009; Crab et al., 2010). Studies demonstrated that biofloc technology in the culture of freshwater fish were all able to synthesize bioflocs and benefited from this additional protein source (Kuhn et al., 2008; Zhao et al., 2014; Wang et al., 2015). Biofloc is beneficial because it does not only promote food security but also it can serve as beneficial tool for overcoming challenges of traditional aquaculture such as climate change and soil degradation. The realization of the potential of biofloc in freshwater communities can also lead to aquaculture initiatives during drought or the El Niño Southern Oscillation (ENSO) where water supply is considerably scarce.

Clarias gariepinus, commonly known as African catfish, large, eel-like fish usually of dark gray or black coloration is considered as major freshwater commodity in inland-based fisheries. Recent adaptations for efficient culture technology have not been applied to this commodity hence the main purpose of this study. The study investigated the potential of bio-floc system application in the larval rearing of African catfish (*C. gariepinus*) with emphasis on the growth and survival of African catfish fingerlings. Specifically, the study aimed to evaluate the effect of different carbohydrate sources in the growth of African catfish (*C. gariepinus*) and the efficiency of biofloc system through total ammonia nitrogen and total suspended solids, and determine which carbohydrate source have significant survival and growth effects in biofloc-cultured African catfish (*C. gariepinus*).

Methodology

Fish and Experimental Set-up

Clarias gariepinus fingerlings were obtained from local source in Midsayap, North Cotabato. Aeration was provided and feed was administered up to 2% of their body weight. Fish were stocked in polyethylene rectangular-shaped tanks with a capacity of 60 liter situated in an outdoor setup at the Department of Fisheries Multi Species Hatchery, University of Southern Mindanao, Kabacan, Cotabato. Tanks were cleaned and disinfected with 100 ppm chlorine prior to stocking. Larval rearing tanks were rinsed thoroughly prior to stocking. During the culture period, all tanks were aerated continuously through an air compressor (20V) and distributed in tanks using air hose and sinkers.

Experimental Design and Growth Trial

Growth trial was conducted for a sixty-day culture period in an outdoor larval set-up (Figure 1). Fish were stocked at 15 individuals per tank to avoid overcrowding. The experiment followed a complete randomized design consisting of four treatments and replicated four times:

Control treatment - conventional method/ without biofloc
BFT/molasses - biofloc treated tanks supplemented with molasses
BFT/rice bran - biofloc treated tanks supplemented with rice bran
BFT/cornstarch - biofloc treated tanks supplemented with cornstarch

For the control, changing of water was done every after three days with 60% of water being replaced through siphoning of tank bottoms. Treatments for biofloc-based culture had zero-water exchange for the whole duration of the culture period.

Figure 1. Experimental set-up for growth trial following complete randomized design.

Preparation of Floc

Floc was generated through the addition of carbohydrate source applied early in the morning in BFT-treated tanks. Carbohydrates (molasses, rice bran and cornstarch) were weighed and added to the culture tanks at daily basis with an estimated C/N ratio of 10 based on recommended application of Avnimelech (1999) assuming that fingerlings produce 10% of their body weight as waste. A uniform ratio were used for all BFT-treated tanks. Floc was assessed through visual inspection and tested for total suspended solids.

Feeding Management

Feeding was provided four times daily (8 am, 11 am, 2 pm and 5 pm). Commercial feeds were used to feed African catfish fingerlings containing 45% crude protein to satisfy the nutritional requirement. Fish stocked per tank were initially weighed to determine initial feeding rate at 30% per body weight. Sampling was done every fifteen days to adjust feeding ration accordingly in all treatments. Feeding rate was adjusted from 30% to 20%, 15% and 10% based on the body weight of African catfish in four sampling periods.

Water Quality Parameters

Fluctuating weather conditions were experienced during the duration of the growth trial. Temperature was measured using thermometer and ranged from 22^{o}C (during cold rainy weather) to 39^{o}C (on hot weather). Sampling of water was done on weekly basis randomly for each treatment and was analyzed for TAN and TSS.

Total Ammonia Nitrogen (TAN)

Water samples (10 mL) for each treatment were analyzed for total ammonia nitrogen using TAN test kit. At the end of the experiment, a graphical representation was showed to demonstrate relationship in flocculation.

Total Suspended Solids (TSS)

The same water samples used for the analysis of TAN were analyzed for TSS. Water samples (200 mL) were collected and were sent to Southeast Asian Fisheries Development Center – Aquaculture Department (SEAFDEC AQD). Analysis was based on standard method for the examination of water and wastewater (APHA, 1998) as well as total suspended solids (TSS).

Sampling and Performance Parameters

Initial and final body weight (g) were recorded at the start and end of the experiment. At the end of the experiment, fish were harvested from the tanks. The following growth parameters were computed:

% Survival rate = [(final count/initial count)] x 100

% Weight gain = [(final body weight – initial body weight)/initial body weight)] x 100

Specific growth rate (SGR)
= [(Ln (final body weight) – Ln (initial body weight) /experimental duration (days)] x 100

Feed conversion ratio (FCR)
= [total dry weight of feed consumed (g)/(final body weight (g) – initial body weight (g)]

Protein efficiency ratio
= [(final body weight – initial body weight/ dietary protein intake)]

Carcass Analysis

At the start of the experiment, 25 g of African catfish (*C. gariepinus*) that was not used for stocking was subjected for initial carcass analysis. At 60-day growth trial experiment, fish in each treatment was collected, pooled, weighed and subjected for proximate analysis of final carcass.

Nutritional composition of fish samples was determined following the methods of AOAC (2001). Moisture content was calculated by constant drying. Crude protein was measured using Kjeldahl method. Crude lipid content was determined using ether extraction with a Soxhlet extractor.

Statistical Analysis

Data was analyzed using one-way ANOVA after homogeneity of variance test. Significant differences were considered at $p<0.05$ confidence level. Duncan's Multiple Range Tests was used to identify differences between experimental groups.

Results

Growth Performance

After 60-day culture period, growth and survival of African catfish (*C. gariepinus*) were evaluated. Biofloc significantly increased survival of African catfish (91-96%) compared to the control (77%) at $p<0.05$ (Table 1).

Supplementation of different carbohydrates showed comparable survival rates in African catfish fingerlings and significantly higher than the control ($p<0.05$). No gross signs of diseases were recorded during the experiment and majority of mortalities observed during the experiment were highly associated with fluctuations of weather particularly abrupt changes from cold to extremely hot temperature in the culture tanks (data not shown).

African catfish in biofloc- treated tanks showed comparable length with the control from initial stocking to final harvest at 60-day culture period (Figure 2). However, supplementation of carbohydrate sources such as rice bran, molasses and corn starch in biofloc-treated tanks enhanced the growth performance of African catfish fingerlings from the initial stocking (0.1) to final harvest (3 g) at 60-day culture period and the % weight gain, SGR and FCR of the fingerlings. Weight gain of African catfish in biofloc-treated

Table 1. Growth and survival parameters of African catfish (*Clarias gariepinus*) after 60 days of culture period.

Treatment	Survival (%)	% Weight Gain (%)	SGR (%)	FCR
Control	$77.78^{b} \pm 3.8$	$551.11^{b} \pm 171.2$	$1.33^{b} \pm 0.19$	$1.36^{a} \pm 0.56$
Rice bran	$91.11^{a} \pm 3.8$	$1156.62^{a} \pm 57.5$	$1.83^{a} \pm 0.03$	$1.28^{b} \pm 0.21$
Molasses	$91.11^{a} \pm 10.2$	$1154.39^{a} \pm 165.2$	$1.82^{a} \pm 0.09$	$1.30^{b} \pm 0.11$
Corn starch	$95.56^{a} \pm 3.8$	$1133.83^{a} \pm 192.1$	$1.81^{a} \pm 0.24$	$1.25^{b} \pm 0.12$

Means ± SD with different superscripts in a column are significantly different ($p<0.05$)
SGR- Specific Growth Rate
FCR- Feed Conversion Ratio

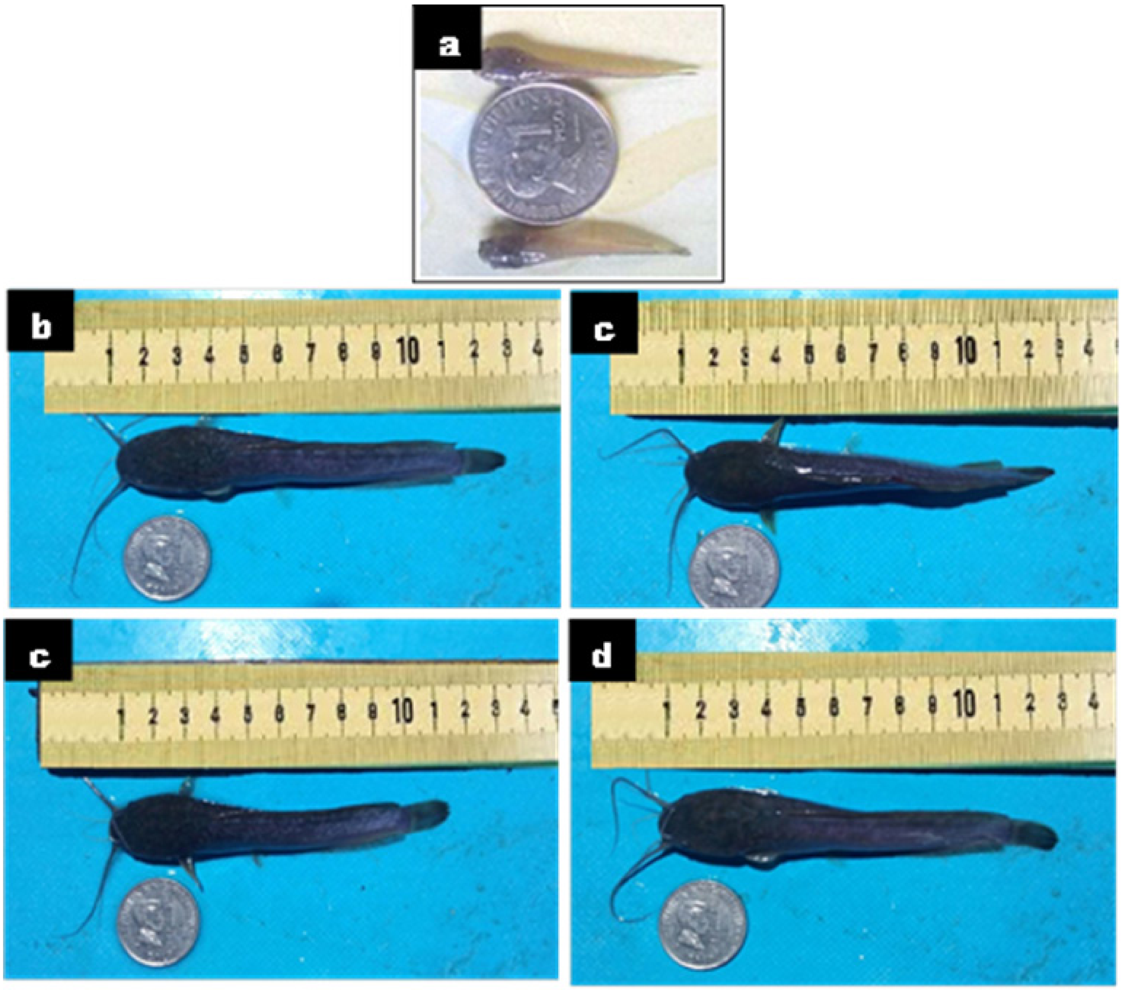

Figure 2. Length (cm) of African catfish (*Clarias gariepinus*) at (A) initial stocking; and after 60-day growth trial in (B) control; biofloc supplemented with (C) rice bran; (D) molasses; and, (E) cornstarch.

tanks increased significantly compared to the control (p<0.05). This was related with increasing SGR in biofloc-treated African catfish fingerlings than in control treatment (p<0.05). Different carbohydrate supplementations were statistically comparable however biofloc supplemented with rice bran showed the highest SGR (1.83).

Positive assimilation of feed was also observed as reflected on lower FCR among biofloc treated African catfish. During the experiment, biofloc-treated *C. gariepinus* fingerlings supplemented with different carbohydrate sources showed significantly lesser feed intake than in control. Thus, FCR was significantly lower in BFT supplemented with carbohydrates than the control (p <0.05).

Water Parameters

The present study evaluated important water quality factors in biofloc system particularly TAN and TSS in the culture of African catfish *C. gariepinus*. Results of the growth trial after sixty days were compared with TAN and TSS parameters in the experiment (Table 2).

Carbohydrate supplementation showed significantly lower TAN in BFT treated tanks than in the control (p<0.05). Lower range of TAN in the BFT system reflected higher survival (%), and weight gain (%) for African catfish fingerlings. Interestingly, TSS was significantly higher in BFT supplemented with rice bran compared to BFT treated with molasses and cornstarch, as well as the control (p<0.05).

Total Ammonia Nitrogen (TAN)

TAN was recorded weekly to compare trend between control and BFT treated tanks (Figure 3). As observed, TAN evidently increased in control tanks until the end of culture period. The same trend was observed in BFT treated tanks with molasses with the highest increase (0.15 to 0.30 ppm), and minimal values for rice bran (0.15-0.20 ppm) and cornstarch (0.15-0.18 ppm).

It was evident that TAN concentrations in control treatment increased from week 2 up to the week 8 of the culture period while in biofloc-treated with rice bran, TAN concentration maintained low concentrations from initial stocking to week 8.

Results showed that TAN initially increased not until the 4th week and was initially lower among the other treatments at stocking (Figure 3). Molasses-treated biofloc exhibited higher TAN concentrations on the 6th week while both rice bran and cornstarch showed minimal TAN concentrations. It can also be noted that TAN in BFT system did not increase beyond 0.4 ppm all throughout the experiment.

Results of the study showed that conventional method is more likely to generate higher TAN concentration (0.19-1 ppm) compared to the biofloc treated fish (0.15-0.38 ppm) in the progression of the culture period. Both rice bran and cornstarch supplementations showed comparable TAN concentrations (0.15-0.2 ppm) which is slightly lower than TAN in cornstarch supplementation (0.15-0.38 ppm).

Total Suspended Solids (TSS)

TSS levels throughout the culture period increased gradually and the changes over time were basically consistent (Figure 4). Flocculation was first observed in rice bran-treated tanks at day 12 of culture period. Cornstarch treated tanks were the last to exhibit flocculation in this study.

Total suspended solids in different treatments showed increasing TSS mean values for BFT supplemented with rice bran (Figure 4) at (p<0.05). TSS from cornstarch supplementation increased twice from initial TSS levels (100 to 201 ppm). On the other hand, TSS levels in molasses treatment slightly decreased on the

Table 2. Water quality parameters of African catfish (*Clarias gariepinus*) control and BFT treated tanks at 60-day period.

Treatment	Total Ammonia Nitrogen (ppm)	Total Suspended Solids (ppm)
Control	$0.575^{a} \pm 0.43$	$148.52^{b} \pm 32.5$
Rice bran	$0.15^{b} \pm 0.04$	$505.60^{a} \pm 42.2$
Molasses	$0.22^{b} \pm 0.13$	$199.02^{b} \pm 53.7$
Corn starch	$0.13^{b} \pm 0.05$	$145.52^{b} \pm 37.5$

Means ± SD with different superscripts in a column are significantly different (p<0.05)

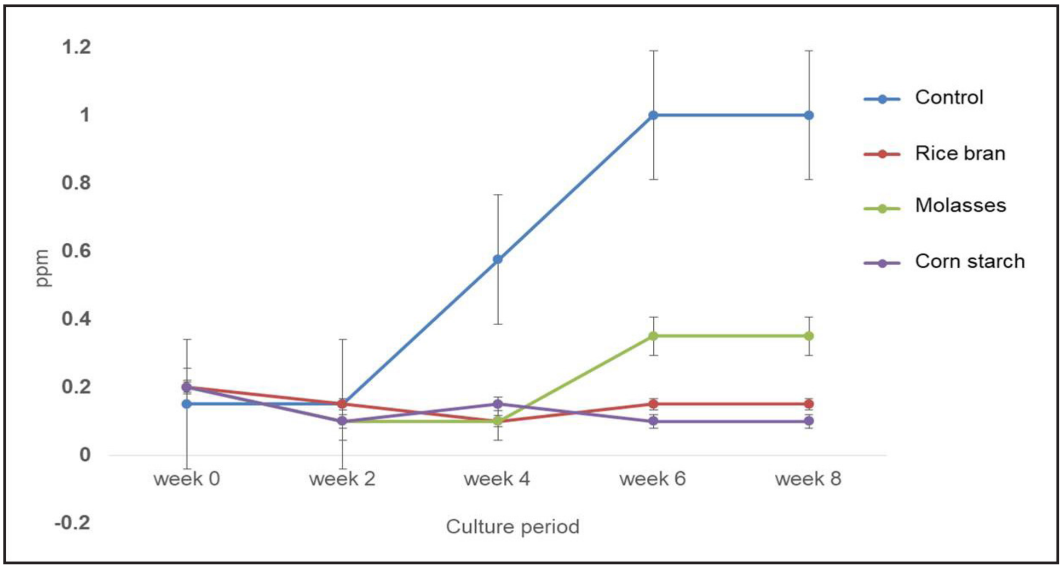

Figure 3. Weekly changes of Total Ammonia Nitrogen (TAN) concentration of biofloc culture in African catfish (*Clarias gariepinus*) fingerlings supplemented with different carbohydrate sources.

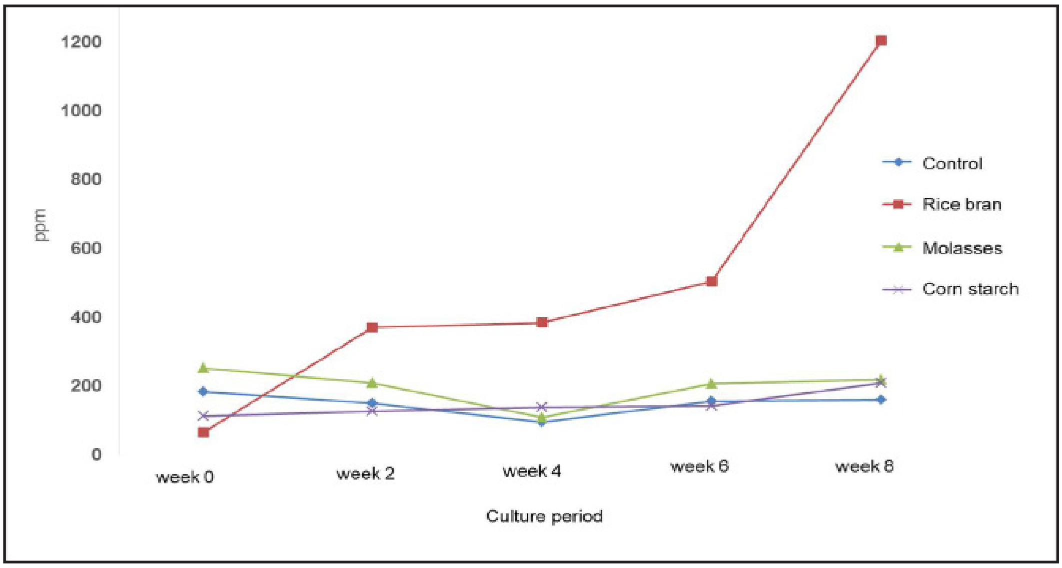

Figure 4. Weekly changes in Total Suspended Solid (TSS) of biofloc culture in African catfish (*Clarias gariepinus*) fingerlings supplemented with different carbohydrate sources.

4th week and maintained at 200 ppm from 6th to 8th week. Control treatment however showed minimum TSS from initial stocking to 8-week culture period (90-190 ppm).

Control treatment showed less TSS mean values for the whole duration of culture period. Biofloc volume and weight stabilized after 6 weeks in both molasses and cornstarch treated tanks with TSS levels of 200 ppm and 219 ppm, respectively. However, TSS levels in rice bran-treated tanks increased as the duration of the culture period increases.

Carcass analysis and protein efficiency ratio

Carcass analysis showed increased protein and lipid compositions after sixty days (Table 3). However, no significant difference was noted among treatments in final protein and lipid composition ($p<0.05$). Protein efficiency ratio (PER) was significantly lower in control compared to biofloc treated tanks ($p< 0.05$).

Based on the result, the control showed high protein composition in the final carcass, but

Table 3. Carcass analysis of African catfish (*Clarias gariepinus*) cultured in control tanks and biofloc-treated tanks after 60 days.

	Initial	Control	Rice bran	Molasses	Corn starch
Protein	52.37	60.91	59.12	58.22	58.60
Lipid	16.27	20.54	20.63	18.39	17.54
Moisture	8.56	14.05	13.60	16.17	16.42
PER*		1.57 ± 0.21^{a}	1.25 ± 0.23^{ab}	1.20 ± 0.12^{b}	1.18 ± 0.04^{b}

Means of PER with different superscripts in a row are significantly different (P<0.05), PER- protein efficiency ratio

resulted to low protein efficiency ratio compared to biofloc treated African catfish. The result of protein retention in the study could have been better supported by determining protein activity to understand digestion and utilization of proteins which could have affected protein retention. Thus the study recommends digestive enzyme assays for future experiments to understand activities of digestive proteinases in the bioflocs treatments, and enhanced digestion and utilization of the feed protein which might resulted to enhanced growth and feed utilization.

Discussion

Survival and Growth Performance

The present study showed that biofloc improved the growth and survival of African catfish *C. gariepinus* fingerlings. The present study agrees with Wang et al. (2015) in carp species, *Carassius auratus* and *Aristichthys nobilis* (Zhao et al., 2014) wherein biofloc treatments enhanced survival up to 100%. Ekasari et al. (2016) cited the immune-stimulating effects of bioflocs through the exposure of African catfish broodstock to microbial rich environment at 14-day *in situ* consumption of bioflocs, which enhanced the survival of larvae produced from biofloc-treated African catfish broodstock. High survival rates of BFT treatments in this study indicate that the culture conditions produced from BFT system were suitable for African catfish fingerlings.

Improved survival was accompanied by positive growth performance in *C. gariepinus* fingerlings. Comparable results in length was observed but weight gain significantly increased in biofloc-treated groups as well as specific growth rate simultaneously. Similar result was observed in other studies in which biofloc increased the percent weight gain of *C. auratus* and *O. niloticus* compared to control treatments (Luo et al., 2014; Wang et al., 2015). Several studies noted the presence of heterotrophic microorganisms that can synthesize protein from organic carbon and inorganic nutrients (Avnimelech, 2006; Hargreaves, 2006). It can be inferred that the presence of bioflocs in the culture water contributed to protein nutrition through improving protein digestion, utilization and retention for the cultured African catfish.

Results suggest that African catfish in biofloc-based tanks had lesser dependency to feeds and may have utilized other food sources which resulted to significantly higher growth performance than in control. This can be reflected through low FCR results but high weight gain yield for African catfish reared in biofloc treatments. Certain components that existed in the bioflocs, may have stimulated digestive proteinases secretion in the digestive gland of the African catfish in some way. High feed conversion ratio in control treatments also imply that feed alone did not suffice nutrition in order for *C. gariepinus* to grow in biofloc-treated tanks. Presumably, as cited in previous studies (Avnimelech, 1999; De Schryver et al., 2008; Crab et al., 2010), heterotrophic microorganisms rely on algae developed from bioflocs. This micro-organisims could sneak through residual feeds and associated wastes and convert then into protein source. Consequently, feed wastes became available as microbial proteins, improving overall feed utilization and protein retention for the African catfish in the present study.

Higher FCR was recorded in the control treatment compared to biofloc treated tanks thus better feed utilization is exhibited by African catfish fingerlings in biofloc systems than in the control treatment. Similar observation was noted in studies applying biofloc in the culture of *Carassius auratus* (Wang et al., 2015), *Hypophthalmichthys molitrix* and *Aristichtys nobilis* (Zhao et al., 2014) at 100% mean survival rates. The reduction of nitrogen coupled by higher TSS could have supported conversion of nitrogen waste into food source which have served as alternative feed. Thus, reducing artificial feed uptake yet not compromising growth of African catfish fingerlings.

Total Ammonia Nitrogen

TAN concentrations recorded in the present study are within the range of values reported from similar biofloc studies of Muangkeow et al. (2007) in Nile Tilapia. Total ammonia nitrogen and total suspended solids reported in this study could confer conversion of nitrogenous waste into carbon source or food in biofloc treated culture. TAN was primarily increased due to decomposition of organic matter such as fish waste, excess feeds and mass algal die-offs as observed in the control. The condition of the set-up could also be a factor, such as direct exposure to sunlight which is suitable for algal mass production. Although water change was practiced in the duration of the experiment for control treatment, fluctuating climatic conditions, occurrence of power interruptions and sudden die-off of algal mass were experienced which are detrimental to cultured fish. Residual decomposed materials and die-offs might have contributed to the increased in TAN concentrations over the duration of the culture period.

However, for biofloc treated tanks, carbohydrate supplementation could have eliminated the detrimental effects of algal die-offs and excess algal growth in the experiment. It could be attributed to conversion of excess nitrogen not only in the algal mass but also from the waste by-products into floc aggregates through the action of flocculation. In the present study, TAN concentrations in rice bran- treated biofloc were consistently lower throughout the experiment which could indicate stable flocculation and therefore efficient conversion of nitrogen into floc.

Theoretically, the process of TAN assimilation in BFT was relatively fast in biofloc treated tanks where sufficient carbonaceous substrate was available. In a demonstration in which sugar was added to a pond containing high levels of TAN, ammonium concentration decreased to approximately minimum value within 5 hours (Avnimelech, 1999). In addition, it was found that within few hours, virtually all of the added ammonium was contained in the biofloc (Avnimelech & Kochba, 2009), which is consistent with the results of the study of Luo et al. (2013).

Total suspended solids

Results were in accordance with the study of Poli et al. (2015) in which South American catfish larvae can be grown in a biofloc system with TSS concentrations up to 1000 ppm, but the best growth was registered in tanks with a higher percentage of volatile suspended solids at 200 ppm.

It could be conferred that BFT using rice bran significantly affected the growth of African catfish fingerlings and showed increasing TSS towards the progression of the culture period. Although cornstarch and molasses showed comparable growth rates, rice bran generated higher TSS levels even on the latter part of the culture on the generation of suspended solids in the form of flocs. It is also evident in the present study that biofloc reduced TAN where production of TSS is high while in the control, TAN increased when TSS decreased. Therefore, it can be inferred that production of TSS contributed to reduction of TAN in the culture system thus improving growth and survival of African catfish fingerlings.

Nutritional effects of biofloc are basically from the aggregations promoted by supplementation of carbohydrate source and developed in the culture water. The aggregates of algae, bacteria, protozoans and other kinds of particulate organic matter such as feces and uneaten feeds were also cited to contribute in the production of bioflocs (Hargreaves, 2013). These aggregations are also referred to as heterotrophic community composed of bacteria and other microorganisms that act as very efficient biochemical systems to degrade and metabolize organic residues (Avnimelech, 1999). In the present study, they were assumed to recycle nutrients in a form of organic and inorganic matter efficiently. Bioflocs has become an emerging aquaculture strategy such that not only it can effectively control the accumulation of ammonium and nitrite in culture systems, but also in turn it becomes an available supplemental food source (Avnimelech, 2007; Kuhn et al., 2008; Ballester et al., 2010).

Carcass Analysis

The present study showed that proteins were not significantly affected by biofloc application. Crab et al. (2010) cited that bioflocs showed an adequate protein, lipid, carbohydrate and ash content for use as an aquaculture feed in the culture of tilapia (*Oreochromis niloticus* x *O. aureus*). The presence of the bioflocs within culture water could have contributed to protein nutrition in African catfish fingerlings.

Although higher protein efficiency ratio was found higher in the control, the PER was not significantly lower in the biofloc treatments. It can be deduced that growth rate is high even at minimal protein efficiency ratio thus biofloc system is efficient in the larval rearing of African catfish fingerlings. Avnimelech (2006) noted that the efficiency of microbial protein assimilation could depend on food particle size for ingestion, digestion and absorption ability in fish. The particle size of the floc might have been suitable for catfish fingerlings thus carbohydrate source was effectively ingested and digested by the fingerlings during the culture period.

Carbon source plays a vital role in the flocculation as this influence the quality of the heterotrophic aggregations that will be generated in the system. Altering the carbon source will also affect the nutritional composition produced in the culture system because the type of carbon source used to produce the flocs influenced nutritional properties of the flocs. Liang et al. (2014) cited bioflocculant as an active substance synthesized by microorganisms in the system and is composed of different polymers, such as glycoprotein, polysaccharide, protein, cellulose and nucleic acid. The different organic carbon sources stimulated beneficial microflora such as bacteria, protozoa, and algae influenced floc composition and thereby also their nutritional properties (De Schryver, 2008; Crab et al., 2009; Crab et al., 2010; Ballester et al., 2010). Differences in carbon source influences characteristic of the floc composition which also affects ingestion, palatability, absorption, assimilation, and digestibility of the cultured organisms (Crab et al., 2009; Crab et al., 2010).

Considering the voracious feeding habits of African catfish, added nutritional supplementation from carbon sources was beneficial. Rice bran as carbon source may have provided better protein utilization and contributed to the enhanced growth of African catfish. Rice bran is the major by-product generated during milling, which is further extracted for oil. The defatted residues of bran according to Hamada (2000) contain 15.4% protein. Han et al. (2015) also reported that rice bran protein has higher nutritional quality than rice endosperm protein; protein efficiency ratio, net protein retention and net protein utilization. Rice bran protein has been noted for its true digestibility at 94.8% and protein digestibility-corrected amino acid score at 0.90.

Wheat bran and molasses accumulated flocs contain 30.4% crude protein and 4.7% crude lipid (Ballester et al., 2010). Studies also have reported that sugarcane extracts have good antioxidant activity (Nagai et al., 2001; Saska & Chou, 2002) while molasses are detected to have melanoidins and phenolic compounds which reported as strong antioxidants (Pant & Adholeya, 2007; Tung et al., 2007) which can explain enhanced survival in treatments supplemented with molasses.

On economical consideration, rice bran cost $0.15 per kg, molasses recently cost $9.57 per gallon and commercial cornstarch costs $0.57 per kg. Among the three carbon sources, rice bran was the cheapest among three carbohydrate source used in this study. Thus, considering the cost of carbohydrate source for large-scale production of African catfish, rice bran would be most cost-efficient to use as carbohydrate source for biofloc culture system.

Conclusion

The present study showed that biofloc can enhance the growth and survival of African catfish *C. gariepinus*. Carbohydrate supplementation was able to synthesize nitrogen waste into suspended solids as floc which have influenced growth of African catfish fingerlings. Biofloc system is beneficial such that it offers minimal requirement for water supply as the culture water is recycled throughout the culture period thus reducing the dependency to water supply. The study concludes that biofloc can be used in hatchery-based production of African catfish fingerlings and rice bran was the most practical to use as carbohydrate supplement for intensive production. The study further recommends for digestive enzyme assays and continuation of growth trial in the grow-out stage for future experiments.

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