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Communication

[*Comunicação*]

BIOFLOC: sustainable alternative for water use in fish culture

[*BIOFLOCO: alternativa sustentável para uso de água na piscicultura*]

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Agro-industry activities consume close to 70% of the water available on the planet, requiring large volumes of water to produce animal protein in conventional systems. In fish farming, it has been estimated that more than five million liters of water are needed to produce 1kg of fish in aquaculture (Tiago and Gianesella, 2003; Ye *et al*., 2017). Due to the increase of aquaculture production, large volumes of effluents are generated, leading to the development of new and more sustainable techniques to mitigate these environmental impacts (Coelho *et al*., 2014).

Production systems that use lower volumes of water than conventional systems such as Recirculating Aquaculture Systems (RAS) and Bio-floc Technology (BFT) are available, but they are not widely used in farms yet. The BFT, especially, can expand the aquaculture production without increasing the use of the basic natural resources (water and land). This technology has become a promising alternative to promote the sustainability and biosecurity of aquatic animals by the utilization of smaller volumes of water, causing less damage to the environment (Avnimelech, 1999; Naylor *et al*., 2000).

Recent studies show that the production of aquatic organisms in BFT, RAS and reduced water exchange presents higher yield than the conventional systems for shrimp and fish (Martins *et al*., 2010; Jatobá *et al*., 2014; Mesquita *et al*., 2016), however, few studies evaluate water use during their experiments. Thus, the goal of this research was to evaluate the growth performance and water consumption by Nile tilapia (*Oreochromis niloticus*) fingerlings reared in Bio-floc Technology (BFT) and the convention
al system.

The study was carried out in the Laboratório de Aquicultura (LAQ), Instituto Federal Catarinense (IFC), campus Araquari, (Protocol number 0190/2017 approved by the animal ethics committee). One hundred Nile tilapia fingerlings (*Oreochromis niloticus*), average weight 1.3±0.2g, were divided into four groups of 250 animals, two were transferred to BFT and the others to the conventional system.

For BFT, three days before the stocking with fish in rectangular tanks (250L), water fertilization was carried out with a carbon source (sugar) and powdered diet to keep the carbon:nitrogen (C:N) ratio 10:1, (Avnimelech, 1999; Ebeling *et al*., 2006) resulting in an initial solids concentration of 200.0mg l^{-1}. Seven days after fish stocking, fertilization was maintained at 10:1 (C:N) to neutralize 40% of the feed nitrogen and to keep the ammonia below 1.0mg L^{-1}. Calcium hydroxide was added when alkalinity fell below 30mg.L^{-1} $CaCO_3$, and when necessary, the dose was 10% of the daily ration. To simulate the conventional system two fiber boxes with 4m³ of water (2.0m x 2.0mx 1.0m) were used, equipped with a constant water renewal system, with water from an artificial lake with phytoplankton and zooplankton.

The initial stocking density was a thousand fish per m³ of water in BFT, and 62.5 fish per m³ of water and conventional system, respectively.

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Fish, in both systems, were fed three times per day (8:00, 11:00 and 16:00), with a commercial diet (GuabiTech QS, 1.0%, 45% crude protein, 8% ethereal extract, 3.0% crude fiber, 1.6% ash, 3.0% calcium, 1.4% phosphorus, manufacturer guarantee levels), with 6% of the fish biomass. Biometric measurements were carried out weekly to check fish growth and adjust the amount of feed offered.

Dissolved oxygen and temperature (YSI55; YSI Incorporated, Yellow Springs, OH, USA) were performed twice a day. Total suspended solids (TSS) (Standard…, 2005 − 2540 D), pH and alkalinity (Standard…, 2005 − 2320 B) were monitored twice a week. Fiberglass microfilters (0.6-m, GF-6 Macherey-Nagel, Düren, Germany) were used for TSS analysis. Ammonia (total ammonia nitrogen − TAN), nitrite-N and nitrate-N phosphate were also monitored twice a week according to APHA (Standard…, 2005).

The final amount of water used by each experimental treatment was expressed in cubic meters of water to produce one ton of fish. The amount of water includes the initial volume used to fill the experimental units and the amount for daily water exchange in the conventional system, or water used to replenish evaporation losses in the BFT. Final weight (g), survival (%), feed conversion ratio (FCR), feed conversion ratio of all inputs (including diet, sugar, calcium hydroxide), protein efficiency ratio, specific growth rate (% day^{-1}) and yield (kg m^{-3}) were used to assess fish performance. Normality and homoscedasticity were assessed by the Shapiro–Wilk and Bartlett tests, respectively, and the t test for averages (Zar, 2010).

The morning temperature, alkalinity, nitrite and nitrate were higher in the BFT than in the conventional system. Total suspended solids and Bio-floc volume were only measured in the BFT. The other parameters did not diverge between the systems (Table 1).

Table 1. Water quality variables in tanks of Nile tilapia fingerlings reared in BFT and conventional system

Variables	BFT	Conventional
Dissolved Oxygen (mg L^{-1}) morning	6.9±1.6	5.2±1.6
Dissolved Oxygen (mg L^{-1}) afternoon	7.0±1.3	6.7±1.4
Temperature (°C) morning	25.1±2.3*	21.7±1.9
Temperature (°C) afternoon	25.2±2.6	24.6±1.2
Bio-Floc volume (cm)	11.4±4.7	Unprocessed
pH	6.9±0.2	7.0±0.1
Alkalinity (mg $CaCO_3$ L^{-1})	37.1±14.2*	16.9±5.4
Ammonia Nitrogen (mg de NH_3 L^{-1})	0.2±0.3	0.1±0.1
Nitrite (mg NO_2^- L^{-1})	48.4±29.7*	0.0±0.0
Nitrate (mg NO_3^- L^{-1})	134.3±90.8*	0.0±0.0
Total suspended solids (mg L^{-1})	206.6±108.6	Unprocessed

*Indicate significant differences ($P < 0.05$) between treatments using t test.

The lower temperatures in the morning reflect the thermal variation that aquatic animals are normally exposed to in nature, but this difference did not affect the growth performance of the animals. Nitrite and nitrate were only detected in the BFT, because the closed system allowed for the stabilization of all the stages of the nitrification process (Avnimelech, 1999; Ebeling *et al*., 2006), while in the conventional system, the constant water renewal probably did not allow the nitrification process to start and stabilize.

Yield is represented by the ratio of the biomass of fish produced per volume of water. The BFT was more than ten times higher than the conventional system; however, final weight and specific growth rate did not differ between systems (Table 2). The BFT is characterized by its high yield, due to the high stock densities used (Michaud *et al*., 2006; Taw, 2010; Jatobá *et al*., 2014), this study was carried out with a difference of 16x between treatments. A lower survival rate was observed in the BFT when compared to the conventional system, and this can be justified by the high stocking density used. This result diverged from Jatobá *et al*. (2014) who observed similar survival in marine shrimp (*Litopenaeus vannamei*) reared in BFT and conventional system.

Table 2. Production data of Nile tilapia (*Oreochomis niloticus*) fingerlings reared in BFT and conventional system

Variables	BFT	Conventional
Final weight (g)	8.48±1.67	9.21±0.98
Survival (%)	95.80±0.85*	100.00±0.00
Feed conversion ratio	1.00±0.10*	1.39±0.12
[1]Feed conversion ratio of all inputs	1.14±0.13*	1.39±0.12
Protein efficiency ratio	2.24±0.21*	1.58±0.31
Specific growth rate (% dia^{-1})	1.56±0.45	2.02±0.39
Yield (kg m^{-3})	7.77±1.39*	0.61±0.07
Volume of water to produce 1.0 T (m^3)	128.21±19.88*	23,934.42±827.86

*Indicate significant differences ($P < 0.05$) between treatments using t test. [1]Including diet, sugar, calcium hydroxide.

Feed conversion ratio and feed efficiency are zootechnical variables that influence the final cost of production in fish culture. Feed conversion ratio was lower in BFT when compared to the conventional system, even when all inputs were considered (diet, sugar and calcium hydroxide), the same tendency was observed by Jatobá *et al*. (2014) who found apparent feed efficiency 10% better for marine shrimp reared in BFT than in the conventional system. This may be related to the biofloc´s ability to offer a natural dietary supplement (Avnimelech, 1999; Jatobá *et al*., 2014). The weight gain was similar in both systems due to the high density of the BFT the trend lines of yield and average weight evolved in parallel. However, average weight evolved more sharply than yield in the conventional system (Figure 1). This result shows that BFT with equal or lower average weight gain is extremely attractive, because it provides a better use of the productive units.

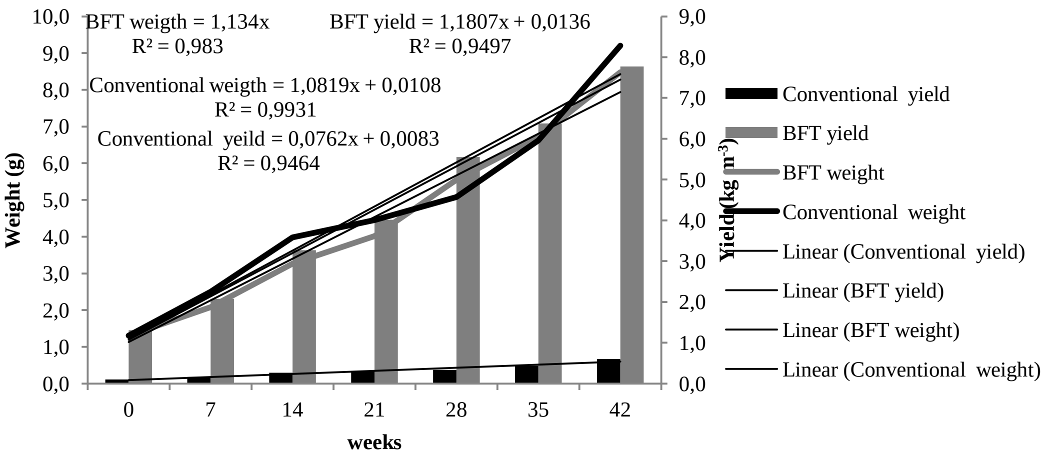

Figure 1. Linear regressions of the mean weight and yield of Nile tilapia (*Oreochromis niloticus*) fingerlings reared in BFT and conventional system.

To promote sustainability in aquaculture, there is a need to develop rearing systems that preserve water quality, as well as reducing water use (Martins *et al*., 2010; Moreira *et al*., 2011). In the present study, BFT used a lower volume of water, requiring 186X less than in the conventional system (Table 2). Based on the data in this study, for each ton of fish it is possible to generate 30g or 2.39kg of ammonia according to the production system chosen, demonstrating that the high concentration of nutrients in the water body of the BFT is compensated by the low volume of water used. This result can be improved, because currently, it is possible to achieve yields above 25kg m^3 of water (unpublished data). This would eventually reduce the demand for water, as well as effluents volume from fish culture, making it more sustainable.

Nile tilapia (*Oreochromis niloticus*) reared in BFT presents equal and/or better productive variables than in conventional systems (with constant renewal), consuming less volume of water. The rearing in BFT decrease the use of water during fish production, as well as limiting the release of effluents to the adjacent environments, making fish farming more sustainable.

Keywords: super-intensive, Oreochromis niloticus, *aquaculture*

RESUMO

Este estudo objetivou avaliar o desempenho do crescimento e o consumo de água de alevinos de tilápia-do-nilo (Oreochromis niloticus) *criados em tecnologia de Biofloco (BFT) e no sistema tradicional. Alevinos de tilápia-do-nilo foram divididos em dois tratamentos: peixes criados em BFT e em sistema convencional. Os peixes foram alimentados três vezes ao dia, com 6% da biomassa corporal. O oxigênio dissolvido e a temperatura foram mensurados duas vezes ao dia; o total de sólidos suspensos, o pH, a alcalinidade, a amônia, o nitrito, o nitrato e o fosfato foram monitorados duas vezes por semana. Após 42 dias, avaliou-se o desempenho do crescimento da tilápia-do-nilo. A temperatura (25,1 e 21,7°C), a alcalinidade (37,1 e 16,9mg L^{-1}), o nitrito (48,4 e 0,0mg L^{-1}) e o nitrato (134,3 e 0,0mg L^{-1}) foram maiores no BFT do que no sistema convencional. A sobrevivência (95,80 e 100,00%), a conversão alimentar (1,00 e 1,39), a conversão alimentar de todos os insumos (1,14 e 1,39) e o volume de água para produzir 1,0 T de peixe (128,21 e 23.934,42m³) foram menores, assim como a proteína, a eficiência (2,24±0,21 e 1,58±0,31) e a produtividade (7,77±1,39 e 0,61±0,07kg.m^{-3}) foram maiores para o BFT do que para o sistema convencional. A tilápia-do-nilo criada em BFT apresenta dados produtivos iguais e/ou melhores que os obtidos em sistemas tradicionais, consumindo menos volume de água.*

Palavras-chave: superintensivo, Oreochromis niloticus, *aquicultura*

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