Revista Ciência Agronômica, v. 50, n. 2, p. 267-275, abr-jun, 2019
Centro de Ciências Agrárias - Universidade Federal do Ceará, Fortaleza, CE
www.ccarevista.ufc.br

Scientific Article
ISSN 1806-6690

The culture of Nile tilapia at different salinities using a biofloc system[1]

Cultivo da tilápia do Nilo em diferentes salinidades utilizando o sistema de bioflocos

Rafael Liano de Souza[2*], Eduardo Cesar Rodrigues de Lima[2], Fabiana Penalva de Melo[3], Maria Gabriela Padilha Ferreira[2] and Eudes de Souza Correia[2]

ABSTRACT - The influence of water salinity on the culture of Nile tilapia with biofloc was evaluated using indicators of water quality, zootechnical performance and animal welfare. Five treatments of different salinities were adopted (0, 4, 8, 12 and 16 g L^{-1}) with three replications. The tilapia were cultured for 90 days and stocked in glass fiber tanks (800 L) at a density of 30 fish m^{-3} with a mean initial weight of 93.8 ± 0.89 g. Water temperature, chlorophyll-*a*, sedimentable solids and total suspended solids showed no difference between salinities (p>0.05). The levels of total ammonia nitrogen (3.94 mg L^{-1}) and nitrite nitrogen (0.82 mg L^{-1}) were lower at the salinity of 0 g L^{-1} compared to the highest salinity (16 g L^{-1}) (p≤0.05). The final weight ranged from 256 to 280 g, with a survival rate of 97 to 100% (p>0.05), which resulted in a productivity of 7.4 to 8.4 kg m^{-3} (p≤0.05). Glucose was above the baseline value (≤ 60 mg.dL^{-1}) in the 16 gL^{-1} treatment (76 mg dL^{-1}), and fish growth at the salinities of 8 and 12 g L^{-1} showed positive allometry (3.020) compared to the other treatments. This demonstrated that it was possible to culture Nile tilapia at salinities of up to 16 g L^{-1}, without compromising performance.

Key words: Fish farming. Brackish water. Microbial floc. *Oreochromis niloticus.*

RESUMO - A influência da salinidade da água no cultivo da tilápia do Nilo com bioflocos foi avaliada por meio de indicadores de qualidade da água, desempenho zootécnico e bem-estar animal. Foram adotados cinco tratamentos, envolvendo salinidades (0, 4, 8, 12 e 16 g L^{-1}) com três repetições. As tilápias foram cultivadas por 90 dias e estocadas em tanques de fibra de vidro (800 L), numa densidade de 30 peixes m^{-3} e com peso médio inicial de 93,8 ± 0,89 g. A temperatura da água, clorofila-*a*, sólidos sedimentáveis e sólidos suspensos totais não diferiram entre as salinidades ($p>0,05$). Os níveis de nitrogênio da amônia total (3,94 mg L^{-1}) e do nitrito (0,82 mg L^{-1}) foram menores na salinidade 0 g L^{-1}, em comparação à maior salinidade (16 g L^{-1}) ($p≤0,05$). O peso final variou de 256 a 280 g, com uma sobrevivência de 97 a 100% ($p>0,05$), que resultou em produtividades entre 7,4 e 8,4 Kg m^{-3} ($p≤0,05$). A glicose esteve acima do valor indicado como basal (≤60 mg dL^{-1}) no tratamento 16 g L^{-1} (76 mg dL^{-1}) e o crescimento dos peixes nas salinidades 8 e 12 g L^{-1} indicou alometria positiva (3,020), comparando-se aos demais tratamentos. Desta forma, constatou-se a possibilidade de cultivar a tilápia do Nilo em salinidades de até 16 g L^{-1}, sem comprometer o desempenho do cultivo.

Palavras-chave: Piscicultura. Água salobra. Floco microbiano. *Oreochromis niloticus.*

DOI: 10.5935/1806-6690.20190031
*Author for correspondence
Received for publication on 14/12/2015; approved on 21/06/2018
[1]Parte da Dissertação de Mestrado em Recursos Pesqueiros e Aquicultura do primeiro autor
[2]Departamento de Pesca e Aquicultura, Universidade Federal Rural de Pernambuco/UFRPE, Rua Dom Manoel de Medeiros, s/n, Dois Irmãos, Recife-PE, Brasil, 52.171-900, rafaelliano@hotmail.com (ORCID ID 0000-0003-3780-4611), educesar19@gmail.com (ORCID ID 0000-0003-2921-4056), mariagabriela.ferreira@gmail.com (ORCID ID 0000-0001-7515-597X), escorreia@uol.com.br (ORCID ID 0000-0002-9987-8854)
[3]Centro de Ciências Agrárias, Universidade Estadual do Maranhão/UEMA, Campus Paulo VI, Tiririca, São Luis-MA, Brasil, 65055-900, fabianapenalva@gmail.com (ORCID ID 0000-0002-0756-578X)

INTRODUCTION

Adaptation to various forms of culture, and resistance to environmental change are among the characteristics that justify the wide use of Nile tilapia in fish farming (EL-SAYED, 2006). Because it is an excellent candidate for culture in low-salinity water (LAWSON; ANETEKHAI, 2011), the production of tilapia in saline environments is a reality in countries such as Taiwan, the Philippines and Malaysia, which are among the largest producers in the world (FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, 2016).

The species *Oreochromis niloticus* displays good development at salinities of 0 to 18 g L^{-1} without impairing its survival (AL-AMOUDI, 1987; SCHOFIELD *et al*., 2011). However, when this species is grown in seawater (> 30 g L^{-1}) its growth is reduced by 60% (CNAANI; HULATA, 2011).

There are certain differences between studies, possibly due to experimental conditions and animal size, since other authors have reported salinities of over 20 gL^{-1} as harmful to the species (KAMAL; MAIR, 2005), while more recent studies have obtained satisfactory results at salinities up to 25 g L^{-1} (PEREIRA *et al*., 2016). Among producers, it is believed that a salinity of 20 g L^{-1} should be the recommended limit.

The addition of fish that can tolerate culture at moderate salinities in systems that allow the reuse of water, is a viable alternative for regions with salinized waters and low rainfall, as well as for polyculture and culture diversification.

Biofloc Technology (BFT) fits into this context by allowing the reuse of water throughout the culture cycle, thereby requiring minimal or no exchange of water. The benefit of this technology is mainly related to the nutritional value of the biofloc produced *in situ* (AVNIMELECH, 2007). In addition, there is a variety of positive aspects to culture using biofloc, including an increase in production indices (AZIM; LITTLE, 2008), high rates of survival (WIDANARNI; EKASARI; MARYAM, 2012) and animal welfare, by guaranteeing acceptable levels of hematological parameters (AZIM; LITTLE, 2008). Other studies also refer to the good water quality provided by bacteria that colonize the biofloc within the production system (AZIM *et al*., 2004).

Some studies report on the effects of salinity in the water used in the culture of Nile tilapia associated with the biofloc system (ALVARENGA *et al*., 2018; KAMAL; MAIR, 2005; LUO *et al*., 2017). Therefore, due to the need for a technology that minimizes environmental impact, and the increasing demand for animal protein, the aim of this study was to evaluate the effect of salinity on the performance of Nile tilapia (*Oreochromis niloticus*) cultured in a biofloc system.

MATERIAL AND METHODS

The experimental culture was carried out at the Continental Fish Farming Station of the Federal Rural University of Pernambuco (UFRPE), from December 2014 to March 2015. The sex-reversed tilapia fingerlings were obtained from the *Companhia de Desenvolvimento do Vale de São Francisco e do Parnaíba* [São Francisco Valley and Parnaíba Development Company - CODEVASF/SE]. The fish were kept in concrete tanks (30 m^3) and fed a commercial diet containing 45% crude protein for 30 days until reaching the juvenile stage.

A completely randomized experimental design with five treatments of five levels of salinity (0, 4, 8, 12 and 16 g L^{-1}) with three replications was used in the study. The culture was conducted in 15 circular glass fiber tanks with a capacity of 1000 L, filled with 800 L of water from the respective treatments, and topped up with 6% of previously matured biofloc from an earlier crop (15 mL L^{-1} sedimentable solids and 2 g L^{-1} salinity). The experimental units were kept under constant aeration in an external area and exposed to natural light; they were covered with screens to avoid the animals escaping, and with protection to prevent salinity destabilization.

The tilapia were stocked at a density of 30 fish m^{-3} with a mean initial weight of 93.8 ± 0.89 g and cultured for 90 days. During stocking, the animals were transferred directly to the proposed salinity levels without the need for previous acclimatization. According to Schofield *et al*. (2011) and Al-Amoudi (1987), Nile tilapia can tolerate levels of 15 and 18 g L^{-1} for direct transfer to the culture environment with no loss of survival.

After stocking the fish, the biofloc was maintained with a daily application of molasses as a source of organic carbon. During the first week of culture, a C to N ratio of 20:1, based on the nitrogen in the feed, was adopted to stimulate microbial development in the experimental environment (AVNIMELECH, 2007). After this period, the C to N ratio was maintained at 6:1, correlated with the levels of nitrogen from the total available ammonia in the culture water (EBELING; TIMMONS; BISOGNI, 2006).

Water-quality variables, such as temperature, dissolved oxygen and pH, were monitored twice daily (8:00 a.m. and 4:00 p.m.), using a YSI 556 MPS multiparameter meter (YSI Incorporation, Ohio, USA). The total ammonia nitrogen (TAN) and nitrite ($N\text{-}NO_2$) were evaluated weekly, while the nitrate (NO_3) and orthophosphate (PO_4) were analyzed every two weeks.

Prior to analysis, the samples were filtered using a 0.45 µm analytical filter. The nitrogen compounds were measured using variations of the HACH TNT method: 830 (salicylate), 8507 (diazotization) and 8539 (cadmium reduction) for NAT, NO_{2}-N and NO_{3}-N respectively. The orthophosphate concentration was measured using the PhosVer®38048 method (ascorbic acid). The samples were analyzed using a HACH DR 2800 digital spectrophotometer (Hach Company, Colorado, USA). The chlorophyll-*a* concentration was analyzed every two weeks, as per Nusch (1988). Total alkalinity was determined by volumetric titration (AMERICAN PUBLIC HEALTH ASSOCIATION, 1995), with the aim of maintaining the concentration at around 150 mg L^{-1} $CaCO_{3}$ due to the consumption of the inorganic carbon by autotrophic bacteria (EBELING; TIMMONS; BISOGNI, 2006). The alkalinity was corrected by the addition of sodium bicarbonate.

The increase in sedimentable solids (SS) was recorded once a week with the use of Imhoff cones, while the total suspended solids (TSS) were monitored every two weeks, using the simplified method described in American Public Health Association (1995). A volume of 100 mL L^{-1} and 1000 mg L^{-1} was adopted as the maximum acceptable level for sedimentable solids and total suspended solids respectively (AVNIMELECH, 2012). As these levels were approached, decantation tanks were installed to control the solids. In addition to these parameters, the volume of water lost through evaporation was also monitored and replaced as necessary.

Biometric evaluations were made weekly of approximately 30% of the population of each experimental unit, using a digital balance (± 0.01 g). This evaluation was used to make adjustments in the amount of feed supplied, and also to obtain estimated results of tilapia growth.

For feeding, a commercial diet including 36% crude protein was offered three times a day (8:00 a.m., 1:00 p.m. and 5:00 p.m.) at a feeding rate of 3% of the total biomass, adjusted according to the weekly biometrics. The influence of salinity on productive performance was evaluated considering such variables as weight gain, daily weight gain, specific growth rate, feed conversion ratio, survival and productivity.

The degree of allometry, to describe the growth of the fish, was determined from the data for weight and length (FROESE, 2006). The weight to length ratio gives the equation $W = aL^b$, where W is the weight, L is the length, and a and b are estimates for the correlation parameters. The values obtained for coefficient b determine the degree of allometry. Hence, if $b = 3$, growth is isometric, with weight gain proportional to length; when $b \leq 3$, there is negative allometry and a greater increase in weight, and if $b > 3$, there is positive allometry, with a more pronounced increase in length than in weight (FROESE, 2006).

At the end of the study, a hematological analysis was carried out using two fish per experimental unit (6 fish/treatment), with a mean weight of 290.12 ± 17.9 g. To do this, clove oil was used as anesthetic (1.5 mL L^{-1} water) and the blood collected by puncturing the caudal vein using a 1 mL syringe and 3% EDTA anticoagulant. The hemoglobin concentration was evaluated with the commercial Hemoglobin Labtest® kit. Hematocrit levels were evaluated using the microhematocrit method (GOLDENFARB; BOWYER; HALL, 1971), with heparin as anticoagulant. Glucose concentrations in the collected blood were also analyzed using the Accu-Chec Activek® meter.

The data were first submitted to the Shapiro-Wilk normality test and to Bartlett's test for homoscedasticity. Analysis of variance (ANOVA) supplemented by Tukey's test ($\alpha = 0.05$) was used to compare performance, water quality and hematological indices; when not meeting the initial proposition, the Kruskal-Wallis non-parametric test was applied. Survival data and hematocrit levels were transformed into arcsen $x^{0.5}$ prior to analysis (ZAR, 1996).

RESULTS AND DISCUSSION

The final mean salinity was 0.66 (± 0.04), 4.18 (± 0.03), 8.11 (± 0.10), 11.94 (± 0.05) and 15.91 (± 0.15) g L^{-1} for the 0, 4, 8, 12, and 16 g L^{-1} treatments respectively. For the salinities under evaluation, temperature, sedimentable solids, total suspended solids and chlorophyll-*a* showed no statistical difference ($p>0.05$), while the dissolved oxygen, pH, ammonia, nitrite, nitrate, alkalinity and orthophosphate differed between treatments ($p\leq0.05$) (Table 1). In general, these variables were maintained within the limits recommended for the culture of tilapia (LUO *et al*., 2014; WIDANARNI; EKASARI; MARYAM, 2012).

The dissolved oxygen (DO) in the treatment of 0 salinity was statistically lower in relation to the other salinities ($p\leq0.05$). This result allows a relationship to be established between salinity and oxygen consumption by the fish. Tilapia show lower energy expenditure in brackish water compared to fresh water or seawater due to smaller differences in the osmotic concentration gradient of the body fluids in relation to the medium, resulting in lower rates of dissolved oxygen consumption (ERN *et al*., 2014).

DO levels below 3.00 mg L^{-1} were recorded in individual cases, with a minimum of 2.17 mg L^{-1} in some treatments (Table 1). It should be emphasized that the

Table 1 - Water-quality variables (mean ± standard deviation: variation in parentheses) in the culture of Nile tilapia (*Oreochromis niloticus*) over 90 days at different salinities in a biofloc system

Variable	Salinity (g L^{-1})					ANOVA (F value)
	0	4	8	12	16	
Temperature (°C)	27.65 ± 1.44 a (23.8 - 31.5)	27.77 ± 1.40 a (23.8 - 31.0)	27.57 ± 1.34 a (23.7 - 30.8)	27.65 ± 1.35 a (23.9 - 31.0)	27.61 ± 1.53 a (23.6 - 30.9)	1.0628^{ns}
DO (mg L^{-1})	4.70 ± 1.06 a (2.24 - 7.62)	5.03 ± 1.03 b (2.46 - 7.68)	5. 15 ± 1.04 b (2.17 - 7.73)	5.10 ± 1.05 b (2.20 - 7.55)	5.11 ± 1.09 b (2.32 - 7.83)	45.2714*
pH	7.60 ± 0.23 a (6.58 - 8.29)	7.54 ± 0.23 b (6.60 – 8.11)	7.50 ± 0.23 b (6.52 - 8.13)	7.45 ± 0.20 c (6.70 - 7.95)	7.40 ± 0.22 c (6.95 - 7.98)	41.5595**
TAN (mg L^{-1})	3.94 ± 1.56 a (0.61 - 7.30)	4.56 ± 1.66 ab (0.47 - 10.60)	4.48 ± 1.78 ab (0.50 - 10.05)	5.27 ± 2.27 b (0.57 - 14.50)	5.84 ± 2.78 b (1.58 - 21.30)	12.8046*
N-NO_2 (mg L^{-1})	0.82 ± 0.83 a (0.001 - 3.84)	4.91 ± 7.97 ab (0.002 - 47.50)	7.14 ± 13.23 ab (0.001 - 43.50)	7.77 ± 15.48 ab (0.001 - 47.20)	8.89 ± 14.45 b (0.002 - 46.90)	2.7515*
NO_3 (mg L^{-1})	65.58 ± 34.95 a (1.30 - 121.6)	49.40 ± 29.38 ab (1.00 - 126.0)	40.58 ± 26.22 b (1.20 - 88.0)	45.73 ± 33.04 ab (1.30 - 131.0)	49.71 ± 34.41 ab (1.20 - 126.0)	9.5603*
Alkalinity (mg L^{-1})	93 ± 25 a (40 - 164)	112 ± 33 ab (40 - 228)	135 ± 51 bc (44 - 272)	140 ± 46 bc (68 - 256)	152 ± 54 c (68 - 280)	36.7124*
Chlorophyll-*a* (mg L^{-1})	28.61 ± 14.61 a (3.28 - 55.8)	35.01 ± 17.20 a (6.56 - 66.96)	26.02 ± 19.47 a (2.79 - 72.54)	27.43 ± 17.02 a (5.19 - 66.96)	22.12 ± 14.26 a (5.58 - 66.69)	1.5757^{ns}
Orthophosphate (mg L^{-1})	13.75 ± 10.20 a (0.59 - 47.20)	5.53 ± 5.08 b (0.74 - 34.0)	6.30 ± 6.68 ab (0.57 - 21.4)	8.76 ± 13.13 ab (0.78 - 73.6)	8.88 ± 6.08 ab (0.59 - 27.6)	10.4289*
SS (mL L^{-1})	27.22 ± 16.02 a (0.0 - 60)	27.50 ± 14.75 a (0.0 - 70)	31.24 ± 17.81 a (0.0 - 100)	26.56 ± 15.61 a (0.0 - 90)	26.38 ± 15.31 a (0.0 - 74)	0.5907^{ns}
TSS (mg L^{-1})	384.5 ± 230.7 a (18.3 - 802.7)	508.0 ± 297.2 a (25.2 - 958.3)	488.4 ± 296.6 a (21.1 - 967.5)	508.1 ± 292.5 a (23.5 - 898.5)	566.9 ± 362.2 a (24.2 -1251)	1.0172^{ns}

DO - dissolved oxygen; TAN - Total ammonia nitrogen; N-NO_2 - Nitrite nitrogen; NO_3 - Nitrate; SS - Sedimentable solids; TSS - Total suspended solids. Values with different letters on the same line show a statistically significant difference between treatments ($p \leq 0.05$). ns – with no significant difference ($p>0.05$). * $p\leq0.05$, ** $p\leq0.01$

addition of a carbon source to the culture system causes an increase in the metabolic activity of the aerobic bacteria present in the culture environment, and because of this there are individual reductions in the levels of dissolved oxygen (DE SCHRYVER *et al*., 2008).

The pH showed a statistical difference between treatments ($p\leq0.05$). Mean values were inversely proportional to the increase in salinity, with a higher mean value for the 0 g L^{-1} treatment (7.60 ± 0.23) (Table 1) and values ranging from a minimum of 6.52 to a maximum of 8.29. The presence of organic matter (feces and leftovers, among others) in the culture tanks results in a decrease in the pH of the water due to respiration and the processes of degradation, assimilation and nitrification carried out by microorganisms, including autotrophic bacteria (AZIM; LITTLE, 2008).

High concentrations of TAN were seen after the first weeks of the study (Figure 1A). In the third week, the 0 and 4 g L^{-1} treatments displayed a mean value for TAN equal to 4.66 and 6.83 mg L^{-1} respectively. These were less significant when compared to the 8 (7.75 mg L^{-1}), 12 (10.78 mg L^{-1}) and 16 g L^{-1} (11.08 mg L^{-1}) treatments. Even with the inoculation of previously matured biofloc (6% of the tank volume), high concentrations of total ammonia nitrogen were recorded for all treatments. Only in the treatment of 0 g L^{-1} salinity did inoculation of the biofloc prove to be slightly efficient (Figure 1A-B).

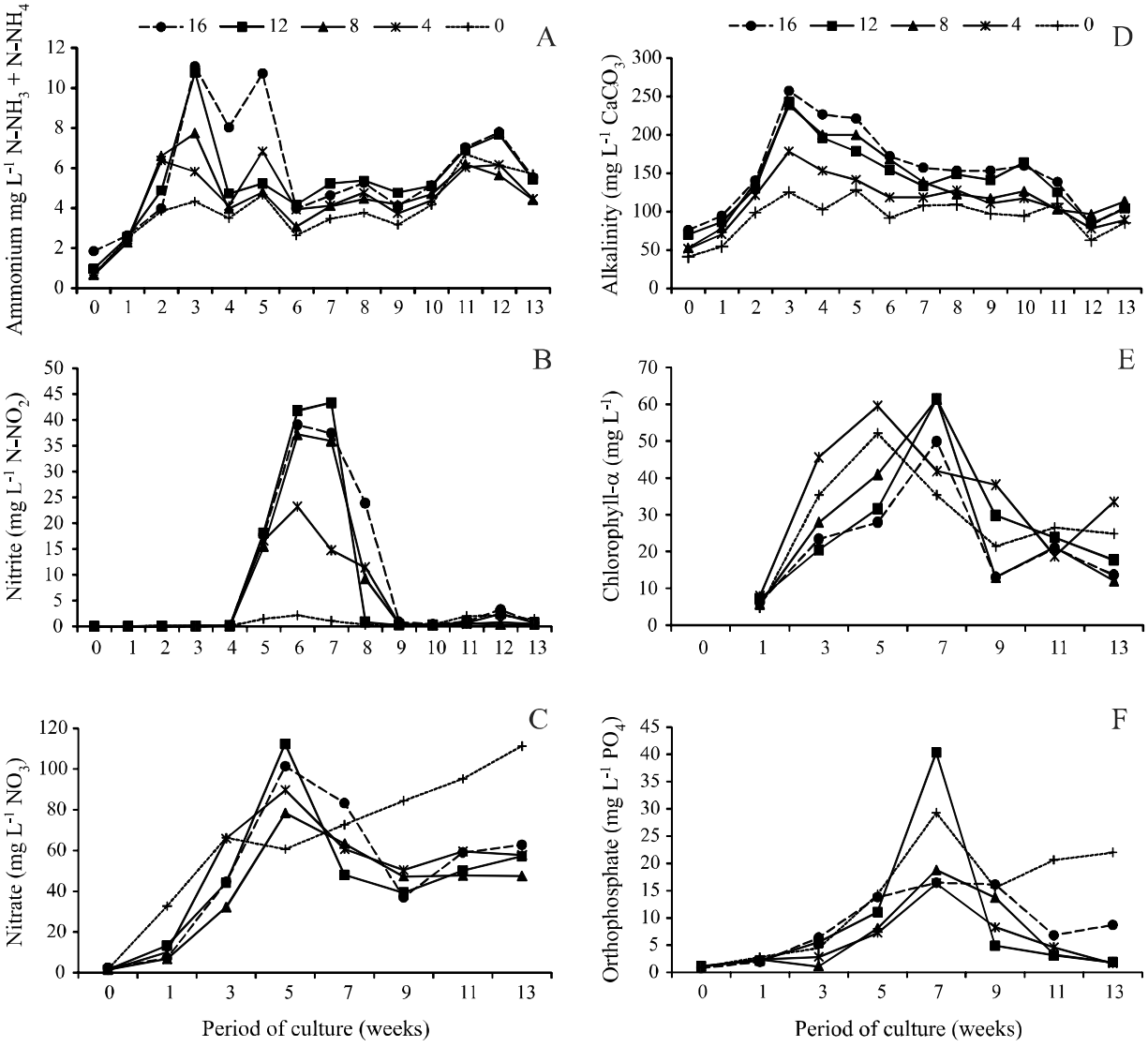
The concentrations of N-NO_2 differed statistically ($p\leq0.05$) between the 0 and 16 g L^{-1} treatments, and remained below 0.136 mg L^{-1} until the fourth week of culture. After this period, between the fifth and eighth weeks, increases were recorded for most of the treatments, with a maximum

of 47.5 mg N-NO_2 L^{-1} in the 12 g L^{-1} treatment, and a decrease in these levels from the eighth week of culture (Figure 1B). According to Azim and Little (2008), the growth of nitrite-oxidizing bacteria (NOB) occurs slowly. This explains the high nitrite levels, except for the 0 g L^{-1} treatment. Under these conditions, the biofloc and water salinity contributed by reducing nitrite toxicity in the fish.

Nitrate levels had a maximum concentration of 121.6, 126.0, 88.0, 131.0 and 126.0 mg NO_3 L^{-1} for the 0, 4, 8, 12 and 16 g L^{-1} treatments respectively (Table 1). However, the nitrate showed a rapid increase for the 0 g L^{-1} treatment during the first week of the study (32.73 mg L^{-1}) (Figure 1C), indicating the beginning of the nitrification process (AZIM; LITTLE, 2008). The conversion of nitrite to nitrate characterizes the second nitrification process (AVNIMELECH, 2012). However, the NO_3 produced can also be reduced to NO_2 and NH_3 by the process of denitrification (LUO *et al*., 2014), a trend seen during the fifth week of this study in the 4, 8, 12 and 16 g L^{-1} treatments (Figure 1C).

The mean values for alkalinity were directly proportional to the increases in salinity, with a significant difference between the salinity of 0 g L^{-1} and the salinities of 8, 12 and 16 g L^{-1} ($p \leq 0.05$), and the salinity of 4 g L^{-1} differing ($p \leq 0.05$) to that of 16 g L^{-1} (Table 1). In addition, there was a greater need for the use of sodium bicarbonate ($NaHCO_3$) to correct the alkalinity at the salinities of 0, 4 and 8 g L^{-1}. Therefore, in the treatments with a lower salinity, the variation in pH due to the lower buffering capacity correlated with the variations in alkalinity, may

Figure 1 - Weekly variation in water quality over 90 days of Nile tilapia culture at different salinities with biofloc technology



explain the statistical differences seen in relation to the higher salinities.

The increase in chlorophyll-*a* concentration between the third and seventh weeks is indicative of the growth of microalgae and coincides with the peaks in alkalinity concentration during the same period (Figure 1 D-E). Similarly, the opposite also took place after the tenth week, with the reduction in alkalinity coinciding with the reduction in chlorophyll-*a*. In the present study, the relationship between chlorophyll and alkalinity can be explained by the removal of CO_2 by microalgae, making the water more alkaline, and generating an increase in the proportion of carbonates from the total inorganic carbon in the culture environment (CAVALCANTE; SÁ, 2010).

There was a significant difference ($p \leq 0.05$) between the salinities of 0 and 4 gL^{-1} for the orthophosphate (PO_4) concentration, with the highest peaks seen during the seventh week of the study in the 0 and 12 gL^{-1} treatments (Figure 1F). However, after this period, there was a reduction; similar to the results obtained by Luo *et al*. (2014). Regardless of the salinity adopted for the culture, the biofloc demonstrated the possibility of maintaining water quality, generating effluents with a low concentration of phosphorus.

There was no statistically significant difference between salinities ($p > 0.05$) for the concentrations of sedimentable solids (SS) or total suspended solids (TSS). The maximum volume of SS achieved in this study was 100 mL L^{-1}, while for TSS it was 1251 mg L^{-1}, with mean values of from 384.5 to 566.9 mg L^{-1} TSS between treatments. These values were similar to those reported by Avnimelech (2007) of from 460 to 643 mg L^{-1}, and were within acceptable limits for the culture of tilapia (AVNIMELECH, 2012). However, it was necessary to install decantation tanks to remove the excess solids, because at high levels these are harmful to the health of the fish (AZIM; LITTLE, 2008).

In relation to fish growth, the final weight ranged from 256.14 to 280.40 g (Table 2) and showed a significant difference between treatments ($p \leq 0.05$). The final weight for the 0 g L^{-1} treatment (280.4 g) was approximately 8.4% higher than for the 8 and 12 g L^{-1} treatments (256.1 and 256.5 g respectively), between which there was a statistical difference ($p \leq 0.05$). The daily weight gain and specific growth rate also differed between the 0, 8 and 12 g L^{-1} treatments ($p \leq 0.05$), while the feed conversion ratio (FCR) only differed between the salinities of 8 and 16 g L^{-1} ($p \leq 0.05$) (Table 2), with values of between 1.4 and 1.6. Similarly, Luo *et al*. (2017), when evaluating the growth of tilapia cultured in a biofloc system at different salinities, obtained a feed conversion of 1.4, 1.39 and 1.46 for salinities of 0, 10 and 20 g L^{-1} respectively. The same authors recorded values for specific growth rate of above 1.75% per day, higher than those found in the present study.

Similar to the present study, Lawson and Anetekhai (2011) obtained low growth rates for the species *O. niloticus* exposed to salinities of 8 and 10 g L^{-1}, in addition to the low appetite of fish exposed to a salinity of 8 g L^{-1}. Mena-Herrera, Sumano-López and Macías-Zamora (2002) also presented similar results when evaluating the growth of hybrid tilapia (*O. mossambicus* x *O. niloticus*). Those authors found no significant difference for final weight, daily weight gain or specific growth rate between the salinities of 0 and 15 g L^{-1}. According to Alvarenga *et al*.

Table 2 - Variables (mean ± standard deviation) of the zootechnical performance of Nile tilapia grown at different salinities in a biofloc system

Variable	Salinity ($g.L^{-1}$)					ANOVA (F value)
	0	4	8	12	16	
Initial weight (g)	94.2 ± 0.6 a	93.3 ± 0.4 a	93.6 ± 1.2 a	94.2 ± 1.1 a	93.7 ± 1.3 a	0.5180^{ns}
Final weight (g)	280.4 ± 7.6 a	263.8 ± 3.8 ab	256.1 ± 10.3 b	256.5 ± 3.8 b	266.5 ± 6.9 ab	6.0870**
Weight gain (g)	186.2 ± 7.7 a	170.5 ± 3.5 ab	162.5 ± 11.0 b	162.3 ± 4.6 b	172.8 ± 6.9 ab	5.5201*
DWG (g dia^{-1})	2.1 ± 0.09 a	1.9 ± 0.04 ab	1.8 ± 0.12 b	1.8 ± 0.05 b	1.9 ± 0.08 ab	5.5021*
SGR (% dia^{-1})	1.2 ± 0.03 a	1.2 ± 0.01 ab	1.1 ± 0.05 b	1.1 ± 0.03 b	1.2 ± 0.03 ab	4.3363*
FCR	1.4 ± 0.06 ab	1.5 ± 0.02 ab	1.6 ± 0.06 a	1.5 ± 0.05 ab	1.4 ± 0.07 b	4.0045*
Survival (%)	100 ± 0.0 a	100 ± 0.0 a	97.2 ± 2.4 a	98.61 ± 2.4 a	100 ± 0.0 a	2.0000^{ns}
Production (Kg)	6.7 ± 0.2 a	6.3 ± 0.1 bc	5.9 ± 0.1 c	6.1 ± 0.1 bc	6.4 ± 0.2 ab	14.1120**
Productivity (Kg m^{-3})	8.4 ± 0.2 a	7.9 ± 0.1 bc	7.4 ± 0.2 c	7.6 ± 0.1 bc	8.0 ± 0.2 ab	14.0518**

DWG - Daily weight gain, SGR - Specific growth rate, FCR - Feed conversion ratio (amount of feed supplied/gain in biomass produced). Values with different letters on the same line show a statistically significant difference between treatments ($p \leq 0.05$). ns - with no significant difference ($p > 0.05$). * $p \leq 0.05$, ** $p \leq 0.01$

(2018), the best growth rates were recorded at salinities of 4 and 8 g L^{-1} for tilapia fingerlings (*O. niloticus*) cultured in a biofloc system.

Survival, which ranged from 97 to 100% (Table 2), did not differ between the salinities under study ($p>0.05$). Mortalities were only seen in the 8 g L^{-1} treatment (two fish) and the 12 g L^{-1} treatment (one fish), due to handling after stocking. Mena-Herrera, Sumano-López and Macías-Zamora (2002), in a culture with no biofloc and with gradual acclimatization to the desired salinity, obtained lower rates of survival (93.5 and 87.1%) for salinities of 0 g L^{-1} and 15 g L^{-1} respectively. Luo *et al*. (2017), in the culture of tilapia (*O. niloticus*) at three different salinities (0, 10 and 20 g L^{-1}) in a biofloc system, recorded a survival rate of from 95 to 97%.

The high rates of survival found in the present study indicate a tolerance to direct transfer to the adopted salinities during stocking, and prove the benefits of biofloc when culturing the species *O. niloticus.* As for tolerance, similar results were found by Schofield *et al*. (2011) and Al-Amoudi (1987) when evaluating the chronic resistance of Nile tilapia, where salinities of 15 and 18 g L^{-1} had no effect on survival (> 90%). Compared to the results obtained with the culture of tilapia in biofloc, the survival rates obtained are quite similar to those reported by Azim and Little (2008) and Crab *et al*. (2009), who obtained rates of 100 and 97%, respectively. When evaluating storage density in a culture of red tilapia (*Orechromis* sp.), Widanarni, Ekasari and Maryam (2012) recorded a survival rate of 97.7, 93.5 and 93% at densities of 25, 50 and 100 fish m^{-3} respectively. Lima *et al*. (2018), in the culture of *Orechromis niloticus* tilapia in a biofloc system with different sources of organic carbon, obtained a survival rate of from 80.3 to 99.1%.

Salinity is a determinant factor in the control of fish growth. According to Boeuf and Payan (2001), osmoregulation can lead to greater energy expenditure in regulating the body fluids of the fish (10 to 50% of the energy balance), which can have negative consequences in relation to oxygen consumption, feeding and hormonal regulation, interfering directly with the performance of the cultured species.

Osmoregulatory capacity varies considerably between species of tilapia. *O. mossambicus* can tolerate a salinity of up to 120 g L^{-1}, whereas red tilapia displays better growth rates between 30 and 35 g L^{-1} (SURESH; LIN, 1992). For Nile tilapia, the best development is restricted to a more limited range of salinity (5-10 g L^{-1}) (SURESH; LIN, 1992). However, it is considered that the degree of genetic purity of the tilapia is capable of significantly affecting performance and adaptation to different environmental conditions, such as a tolerance to salinity (VILLEGAS, 1990). In this context, the size and age of the fish should also be taken into account (WATANABE *et al*., 1990), as well as the methods of acclimatization used in stocking the animals, whether carried out by direct or gradual transfer to the desired salinity (AL-AMOUDI, 1987).

When the state of health of the fish was evaluated by analyzing the glucose, hemoglobin and hematocrit, indications of stress were found for the 16 g L^{-1} treatment only; these factors are wholly attributed to the level of salinity. Epithelial ulceration, scaling, and damage to the dorsal, pectoral and anal fins were only seen in this treatment; however, no physical changes were seen in fish submitted to the other treatments.

Furthermore, at a salinity of 16 g L^{-1}, glucose levels were between 47 and 121 mg dL^{-1}, with a mean value of 76 ± 32.0 mg dL^{-1} (Table 3), differing from the other treatments ($p\leq0.05$). On the other hand, the concentrations obtained with the 0, 4, 8, 12 g L^{-1} treatments had values that were within the limit considered the baseline for fish, and therefore less than 60 mg dL^{-1} (VIJAYAN *et al*., 1997). Glucose is a side product of the release of cortisol, which, in its function as a glucocorticoid, stimulates glycogenolysis and hepatic gluconeogenesis (SILVA *et al*., 2012), and which characterizes it as an important evaluation tool.

Table 3 - Hematological variables (mean ± standard deviation) of Nile tilapia (*Oreochromis niloticus*) after 90 days grown at different salinities in a biofloc system

Variable	Salinity(g.L^{-1})					ANOVA (F value)
	0	4	8	12	16	
Glucose (mg dL^{-1})	44.8 ± 12.0 a	38.1 ± 12.2 a	37.8 ± 9.1 a	28.3 ± 3.9 a	76.0 ± 32.0 b	7.0690**
Hemoglobine (g dL^{-1})	7.9 ± 2.7 a	7.5 ± 2.0 a	10.5 ± 0.8 a	9.7 ± 2.2 a	8.9 ± 0.9 a	1.4469^{ns}
Hematocrit (%)	31.4 ± 1.1 a	33.3 ± 3.7 a	34.8 ± 5.3 a	31.6 ± 5.2 a	29.1 ± 5.4 a	2.4951^{ns}

Values with different letters on the same line show a statistically significant difference between treatments ($p \leq 0.05$). ns – with no significant difference ($p>0.05$). * $p\leq0.05$, ** $p\leq0.01$

Hemoglobin and hematocrit levels showed no significant variation between treatments (Table 3), the levels were similar to those of tilapia cultured in an extensive system (TAVARES-DIAS; FAUSTINO, 1998), and were higher than those reported by Azim and Little (2008) for a culture with biofloc.

In relation to the developmental pattern of the fish, and according to the classification established by Froese (2006), differences were seen between the 0, 4 and 16 g L^{-1} treatments (2.967, 2.969 and 2.796 respectively), all with a negative allometry. For the 8 and 12 g L^{-1} treatments, the value of *b* (3.020) indicated a positive allometry for both treatments; this result explains the low values for the final weight of the fish exposed to these salinities. However, the values of *b* are within the range recommended by Froese (2006) when he stated that this parameter varies between 2.5 and 4.

In short, most of the studies that address the culture of tilapia using BFT were developed in fresh water, and report significant increases related to their productive performance (AZIM; LITTLE, 2008; LUO *et al.*, 2014; WIDANARNI; EKASARI; MARYAM, 2012). However, further research is necessary to draw comparisons between the culture of tilapia in traditional systems and in biofloc systems in a saline medium.

CONCLUSIONS

1. Biofloc technology developed in salinities ranging from 0 to 16 g L^{-1} have proved to be suitable for the culture of tilapia, as the water quality was maintained in the proper conditions for fish performance with high rates of survival;
2. A rise in glucose levels, added to a visual evaluations of the body integrity of fish exposed to the salinity of 16 g L^{-1}, indicate that this concentration may be a condition of stress for the tilapia;
3. The performance of the culture was not affected by the levels of salinity, and it is therefore possible to culture the species *O. niloticus* at salinities of up to 12 g L^{-1} in a biofloc system.

ACKNOWLEDGEMENTS

The authors would like to thank the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) for the Master's scholarship offered to the lead author. Thanks are also due to the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) for their financial support to carry out this research.

REFERENCES

AL-AMOUDI, M. M. Acclimation of commercially cultured *Oreochromis* species to seawater- an experimental study. **Aquaculture**, v. 65, n. 3, p. 333-342, 1987.

ALVARENGA, E. R. *et al*. Moderate salinities enhance growth performance of Nile tilapia (*Oreochromis niloticus*) fingerlings in the biofloc system. **Aquaculture Research**, p. 1-8, May 2018.

AMERICAN PUBLIC HEALTH ASSOCIATION. Standard methods for the examination of water and wastewater**. 1**9th ed. Washington, D.C.: APHA, 1995, 1082 p.

AVNIMELECH, Y. Biofloc technology: a practical guide book. 2nd ed. Baton Rouge: The Word Aquaculture Society, 2012. 271 p.

AVNIMELECH, Y. Feeding with microbial flocs by tilapia in minimal discharge bio-flocs technology ponds. **Aquaculture**, v. 264, n. 1/4, p. 140-147, 2007.

AZIM, M. E; LITTLE, D. C. The biofloc technology (BFT) in indoor tanks water quality, biofloc composition, and growth and welfare of Nile tilapia (*Oreochromis niloticus*). **Aquaculture**, v. 283, n. 2, p. 29-35, 2008.

BOEUF, G.; PAYAN, P. How should salinity influence fish growth? **Comparative Biochemistry and Physiology**, v. 130, n. 4, p. 411-423, 2001.

CAVALCANTE, D. de H.; SÁ, M. C. V. Efeito da fotossíntese na alcalinidade da água no cultivo da tilápia do Nilo. **Revista Ciência Agronômica**, v. 41, n. 1, p. 67-72, 2010.

CNAANI, A.; HULATA, G. Improving salinity tolerance in tilapias: past experience and future prospects. **The Israeli Journal of Aquaculture**, v. 63, n. 1, p. 1-21, 2011.

CRAB, R. *et al*. Bio-flocs technology application in over-wintering of tilapia. **Aquacultural Engineering**, v. 40, n. 3, p. 105-112, 2009.

DE SCHRYVER, P. *et al*. The basics of bio-flocs technology: the added value for aquaculture. **Aquaculture**, v. 277, n. 1, p. 125-137, 2008.

EBELING, J. M.; TIMMONS, M. B.; BISOGNI, J. J. Engineering analysis of the stoichiometry of photoautotrophic, autotrophic, and heterotrophic removal of ammonia-nitrogen in aquaculture systems. **Aquaculture**, v. 257, n. 3, p. 346–358, 2006.

EL-SAYED, A. -F. M. Tilapia culture. Wallingford, Oxfordshire: CABI Publishing, 2006. 277 p.

ERN, R. *et al*. Effect of salinity on oxygen consumption in fishes: a review. **Journal of Fish Biology**, v. 84, n. 4, p. 1210-1220, 2014.

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS. Fishery Information, Data and Statistics Unit. FishStat J: universal software for fishery statistical time series. Version 2.1.0. Rome, 2016. Disponível em: <http://www.fao.org/fishery/statistics/software/fishstatj/en>. Acesso em: 10 de abril de 2018.

FROESE, R. Cube law, condition factor and weight–length relationships: history, meta-analysis and recommendations. **Journal of Applied Ichthyology**, v. 22, n. 4, p. 241-253, 2006.

GOLDENFARB, P. B.; BOWYER, F. P.; HALL, E. Reproducibility in the hematology laboratory: the microhematocrit determination. **American Journal of Clinical Pathology**, v. 56, n. 1, p. 35-39, 1971.

KAMAL, A. H. M. M.; MAIR, G. C. Salinity tolerance in superior genotypes of tilapia, *Oreochromis niloticus*, *Oreochromis mossambicus* and their hybrids. **Aquaculture**, v. 247, p. 189-201, 2005.

LAWSON, E. O.; ANETEKHAI, M. A. Salinity tolerance and preference of hatchery reared Nile tilapia, *Oreochromis niloticus* (Linneaus, 1758). **Asian Journal of Agricultural Sciences**, v. 3, n. 2, p. 104-110, 2011.

LIMA, E. C. R. *et al*. Culture of Nile tilapia in a biofloc system with different sources of carbon. **Revista Ciência Agronômica**, v. 49, n. 3, p. 458-466, 2018.

LUO, G. *et al*. Comparing salinities of 0, 10 and 20 in biofloc genetically improved farmed tilapia (*Oreochromis niloticus*) production systems. **Aquaculture and Fisheries**, v. 2, p. 220-226, 2017.

LUO, G. *et al*. Growth, digestive activity, welfare, and partial cost-effectiveness of genetically improved farmed tilapia (*Oreochromis niloticus*) cultured in a recirculating aquaculture system and an indoor biofloc system. **Aquaculture**, v. 422-423, n. 2, p. 1-7, 2014.

MENA-HERRERA, A.; SUMANO-LÓPEZ, H.; MACÍAS-ZAMORA, R. Effects of water salinity on the growth of hybrid red tilapia *Oreochromis mossambicus* (Peters) x *Oreochromis niloticus* (Linnaeus), cultured under controlled laboratory conditions. **Veterinaria México**, v. 33, n. 1, p. 39-48, 2002.

NUSCH, E. A. Comparison of different methods for chlorophyll and phaepigment determination. **Archiv für Hydrobiologie Beiheft Ergebnisse der Limnologie**, v. 14, n.11, p. 14-36. 1988.

PEREIRA, D. S. P. *et al*. Parâmetros hematológicos e histológicos de tilápia do Nilo em resposta ao desafio de diferentes níveis de salinidade. **Boletim do Instituto de Pesca**, v. 42, n. 3, p. 635-647, 2016.

SCHOFIELD, P. J. *et al*. Survival, growth and reproduction of non-indigenous Nile tilapia, *Oreochromis niloticus* (Linnaeus 1758). I. Physiological capabilities in various temperatures and salinities. **Marine and Freshwater Research**, v. 62, n. 5, p. 439-449, 2011.

SILVA, R. D. *et al*. Parâmetros hematológicos e bioquímicos da tilápia do Nilo (*Oreochromis niloticus* L.) sob estresse por exposição ao ar. **Pesquisa Veterinária Brasileira**, v. 32, n. 1, p. 99-107, 2012.

SURESH, A. V; LIN, C. K. Tilapia culture in saline waters: a review. **Aquaculture**, v. 106, n. 3/4, p. 201-226, 1992.

TAVARES-DIAS, M.; FAUSTINO, C. D. Parâmetros hematológicos da tilápia do Nilo *Oreochromis niloticus* (Cichlidae) em cultivo extensivo. **Ars Veterinária**, v. 14, n. 3, p. 254-263, 1998.

VIJAYAN, M. M. *et al*. Metabolic responses associated with confinement stress in tilapia: the role of cortisol. **Comparative Biochemistry and Physiology**, v. 116C, n. 1, p. 89-95, 1997.

VILLEGAS, C. T. Evaluation of the salinity tolerance of *Oreochromis mossambicus*, *O. niloticus* and their F1 hybrids. **Aquaculture**, v. 85, n. 1/4, p. 281-292, 1990.

WATANABE, W. O. *et al*. Culture of Florida red tilapia in marine cages: the effect of stocking density and dietary protein on growth. **Aquaculture**, v. 90, n. 2, p. 123-134, 1990.

WIDANARNI; EKASARI, J.; MARYAM, S. Evaluation of biofloc technology application on water quality and production performance of red tilapia *Oreochromis* sp. cultured at different stocking densities. **HAYATI Journal of Biosciences**, v. 19, n. 2, p. 73-80, 2012.

ZAR, J. H. Biostatistical analysis. New Jersey: **Prentice Hall**, 1996. 662 p.