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Interaction between afternoon aeration and tilapia stocking density

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ABSTRACT. The present study aimed at determining the effects of the interaction between afternoon aeration and stocking density of Nile tilapia on variables of water and soil quality, growth performance and effluent quality. The experiment was a 3 x 2 factorial randomized block design, with three stocking densities (8, 12 and 16 fish per tank or 43.5, 65.3, and 87.0 g m^{-3}) under two mechanical aeration regimes, absence (control; three replicates) and afternoon aeration (four replicates). The afternoon aeration was carried out from 12.00 a.m. up to 18.00 p.m. from the 3rd week until the end of the experiment. Except for the 16-fish tanks, the lowest concentrations of total ammonia nitrogen were found in the tanks with higher density of fish provided with afternoon aeration. Nitrite concentrations were lower in the 8-fish aerated tanks. In intensive system, the afternoon aeration of the fish culture water is an efficient management of water quality to remove gaseous ammonia and nitrite from water, but it is not appropriate to remove hydrogen sulfide from water.

Keywords: fish farming, total ammonia nitrogen, unionized ammonia, nitrite.

Interação entre aeração vespertina e densidade de estocagem na criação de juvenis de tilápia

RESUMO. O presente trabalho teve por objetivo determinar os efeitos da interação entre a aeração vespertina da água e a densidade de estocagem de juvenis de tilápia do Nilo sobre variáveis de qualidade de água, solo, desempenho zootécnico e qualidade de efluentes. O delineamento experimental adotado foi em blocos ao acaso, em arranjo fatorial 3 x 2. Havia três densidades de estocagem (8, 12 e 16 peixes por tanque ou 43,5; 65,3 e 87,0 g m^{-3}, respectivamente), em dois regimes de aeração mecânica da água, ausência (controle; três repetições) e aeração vespertina (quatro repetições). A aeração vespertina da água ocorreu das 12 às 18 h, da terceira até a última semana de criação. Exceto pelos tanques com 16 peixes, menores concentrações de nitrogênio amoniacal total foram observadas nos tanques de maior densidade de estocagem providos de aeração vespertina. As concentrações de nitrito da água foram menores nos tanques com 8 peixes e aeração vespertina. A aeração vespertina da água de cultivo de peixes é um eficiente manejo de qualidade de água para remoção de amônia gasosa e nitrito da água em sistemas intensivos, não sendo indicado, entretanto, para remoção de gás sulfídrico da água.

Palavras-chave: piscicultura, nitrogênio amoniacal total, amônia não-ionizada, nitrito.

Introduction

In aquaculture, one of the management strategies for better use of the available natural resources is the employment of high animal stocking densities (Seginer, 2009). These intensive and superintensive systems require the use of specific equipment and appropriate management practices to obtain good growth performance. In these systems, the mechanical aeration of water is indispensable for maintaining adequate concentrations of dissolved oxygen in water. In contrast, farming intensification leads to a deterioration of water quality, producing effluents that negatively influence the receiving water bodies. According to Stigebrandt (2011), the use of stocking densities higher than the environmental carrying capacity negatively affects the growth rate of the farmed animals and water quality.

Das, Jena, Mishra, and Pati (2012), Pawar, Jena, Das, and Bhatnagar (2009) and Pawar, Jena, and Das (2014) showed that the use of overnight water aeration significantly improved the growth and survival of the farmed animals in high density tanks. In addition to the use of nocturnal aeration of water, which is already a consolidated management among farmers, new strategies should be sought to control water quality and obtain better productive results in intensive aquaculture systems. Among the alternatives proposed, we highlight the use of afternoon aeration.

Traditionally, the use of afternoon aeration aims to prevent the estratification of the water column and thereby the formation of toxic gases, as demonstrated by Kimpara et al. (2013a). Besides this, another usual goal of the afternoon aeration is the increase in the concentration of dissolved oxygen in water in cloudy and rainy days (Qayyum, Ayub, & Tabinda, 2005). In the afternoon, fish may suffer from stress by unionized ammonia (NH_3) due to the increase in water pH and temperature. For that reason, afternoon is the ideal period to remove ammonia by volatilization (Gross, Boyd, & Wood, 1999). A previous study conducted in our laboratory indicated that afternoon aeration significantly reduced the total ammonia nitrogen (NAT) and NH_3 in Nile tilapia's rearing waters. In that work, however, the fish growth performance was not improved. We hypothesized that the positive effects of afternoon aeration on fish growth rate would be achieved only in more intensive farming systems, where there is a high biomass of fish stocked in the tanks.

This study aimed to determine the effects of the interaction between afternoon aeration and the stocking density of Nile tilapia on variables of water and soil quality, growth performance and effluent quality.

Material and methods

The study was conducted in the LCTA – Laboratório de Ciência e Tecnologia Aquícola, a research unit of the Fisheries Engineering Department, Agrarian Science Center, Universidade Federal do Ceará (Fortaleza, Ceará State). Masculinized juvenile Nile tilapia (*Oreochromis niloticus*) with a body weight of 0.90 ± 0.13 g were obtained from a regional farmer and transported to the laboratory. For an initial period of four days, fish were acclimated to the laboratory conditions, kept in one 1,000-L circular tank. At this stage, fish were fed four times daily at 8, 11, 14 and 17h with a commercial diet designed for omnivorous tropical fish (40.3% crude protein). The daily feeding rate was 10% of the stocked biomass.

After the acclimation period, juvenile tilapia with a body weight of 1.36 ± 0.03 g were distributed and maintained for eight weeks in 21 outdoor 250-L tanks at different stocking densities. Each tank received a 5-cm layer of coarse sand to allow the water-soil interactions occurring in a fishpond. No water exchange was made throughout the experimental period, only maintainance of the initial level. The experiment was a 3 x 2 factorial randomized block design with three different stocking densities, i.e., 8, 12 and 16 fish per tank (43.5, 65.3, 87.0 g m^{-3}, respectively), and two mechanical aeration regimes: absence (control) and afternoon aeration, the latter runing from 12 to 18h (6h aeration day^{-1}). There were three replicates per treatment for the tanks without aeration and four replicates per treatment for tanks provided with afternoon aeration. The afternoon aeration was carried out using a 2.5-HP radial compressor (air blower), PVC pipes, silicone hoses and porous stones. The mechanical aeration of water started off from the third experimental week until the end of the experiment.

Daily, the water pH was determined using a MS Tecnopon pHmeter model PA210, at 8 and 15h. Twice a week, the electrical conductivity and temperature of the water were determined at 9 and 15h with a conductivity meter (Instrutherm, model CD-850), and a digital thermometer, respectively. Weekly, tank water samples were obtained at 9h to measure the concentrations of dissolved oxygen (DO_2; YSI 55 oxymeter) and total ammonia nitrogen (TAN; indophenol method). The concentrations of unionized ammonia (NH_3) in water were obtained by applying the results of TAN, pH and water temperature into the Emerson's formula (El-Shafai, El-Gohary, Nasr, Van Der Steen, & Gijzen, 2004).

Fortnightly, the following water quality determinations were performed: total alkalinity (titration with standard H_2SO_4 solution), total hardness (titration with standard EDTA solution), reactive phosphorus (molybdenum blue method), nitrite (sulfanilamide method), nitrate (cadmium column method), free carbon dioxide (titration with standard Na_2CO_3 solution), soluble iron (Herapath method), total dissolved sulfide (TDS; titration with standard $Na_2S_2O_3$ solution). The concentrations of hydrogen sulfide (H_2S) in water were obtained by applying the appropriate coefficients to the TDS, pH and water temperature results (Lahav, Ritvo, Slijper, & Hearne, 2004). All determinations of water quality followed the guidelines of American Public Health Association (APHA, 1999). The soil pH and organic carbon concentration were determined at the beginning, middle and end of the experiment according to Han, Boyd, and Viriyatum (2014). In the 7th experimental week, diel monitoring was performed to analyze the concentrations of TAN, NH_3 DO_2 every two hours, plus the recordings of water pH and temperature of all experimental tanks. Samples of the tank effluents were obtained 48 h after the final fish weighings. In those samples, the pH, electrical conductivity, DO_2, TAN, nitrite, reactive phosphorus, hydrogen sulphide and organic matter concentrations were determined by the same foregoing methods.

The variables of growth performance monitored were the followings: survival, final body weight, weekly weight gain ((final body weight - initial body weight) number of weeks^{-1}), specific growth rate (SGR = [(Ln final body weight - Ln initial body weight) number of days^{-1}] x 100), fish yield = [gain in biomass (g) tank volume^{-1} (m^3) day^{-1}], feed conversion ratio (FCR = feed allowed weight gain^{-1}) and protein efficiency ratio (PER = fish weight gain protein supplied^{-1}).

The variables of water and soil quality, tank effluent and growth performance were analysed by a two-way ANOVA, with the stocking density and the afternoon aeration as main factors. Before the analysis, the assumptions of normal distribution and homogeneity of variance were checked by the Shapiro-Wilk and the Levene tests, respectively. tukey's test was used for comparisons between means with significant differences. It was adopted a 5% significance level in all statistical tests. The statistical analyses were run with the aid of the software SPSS v.22 for Windows and Microsoft Excel 2010.

Results and discussion

Water and soil quality

The average temperature of the tank water was 28.2 ± 1.9°C with a minimum of 25.7 and maximum of 30.6°C. The afternoon aeration and the different stocking densities had no significant effect on water pH, electrical conductivity and dissolved oxygen (Table 1). These results demonstrate that the afternoon aeration is a management not valid to increase the DO_2 concentration in water.

Total alkalinity, total hardness and free CO_2 concentrations of rearing water increased with increasing fish stocking density ($p < 0.05$), but with no significant effects of afternoon aeration on those variables (Table 1). There is a higher concentration of decomposing organic matter in water derived from fish faeces and unconsumed feed with the increase in fish stocking density. That way, there is a greater release of CO_2 in more intensive farming tanks (Cavalcante & Sá, 2010).

The nocturnal aeration of water is a more efficient management than the afternoon aeration in removing CO_2 from the water because, unlike what happens at night, there is little or even no CO_2 in the water during the afternoon (Cavalcante, Poliato, Ribeiro, Magalhães, & Sá, 2009).

The increase in hardness in the highest stocking density tanks could be explained by the greater input of calcium by the artificial feeding carried out in those tanks (Cavalcante, Caldini, Silva, Lima, & Sá, 2014).

Except for the 16-fish tanks, lower concentrations of TAN and NH_3 were observed in the tanks with increased stocking density, provided with afternoon aeration ($p < 0.05$; Table 2). This result demonstrates that the afternoon aeration of the water can efficiently remove gaseous ammonia from the water, which support the findings of Gross et al. (1999).

Unlike what was observed in the non-aerated tanks, the NH_3 increase in the afternoon-aerated tanks, caused by the higher fish stocking density, was not significant ($p > 0.05$). Therefore, the afternoon aeration halted the NH_3 increase. The concentrations of TAN and NH_3 were higher in the tanks with the highest stocking densities (12 and 16 fish per tank; $p < 0.05$). Das et al. (2012) also observed an increase in TAN concentrations along with the stocking densities in *Puntius gonionotus* tanks.

Table 1. pH, electrical conductivity, dissolved oxygen, total alkalinity, total hardness and carbon dioxide of juvenile Nile tilapia tanks (initial body weight = 1.36 ± 0.03 g). The rearing tanks were stocked with different fish densities and were subjected or not to afternoon aeration (mean ± SD).

Variable	Number of fish per tank	Water aeration		Two-way ANOVA	
		None	Afternoon	Factor	P
pH[1]	8	8.32 ± 0.11	8.39 ± 0.03	Density	ns[2]
	12	8.30 ± 0.12	8.40 ± 0.07	Aeration	ns
	16	8.34 ± 0.08	8.39 ± 0.03	D x A	ns
Electrical conductivity (μS cm^{-1})	8	765 ± 15	771 ± 32	Density	ns
	12	788 ± 22	763 ± 33	Aeration	ns
	16	787 ± 42	764 ± 13	D x A	ns
Dissolved oxygen (mg L^{-1})	8	4.29 ± 0.36	4.27 ± 0.29	Density	ns
	12	3.68 ± 0.79	3.73 ± 0.30	Aeration	ns
	16	3.64 ± 0.60	3.62 ± 0.30	D x A	ns
Total alkalinity (mg L^{-1} $CaCO_3$ eq.)	8	133.67 ± 1.53 A[3]	130. 33 ± 1.53 A	Density	0.009
	12	137.67 ± 5.51 A	134.33 ± 3.79 A	Aeration	ns
	16	140.00 ± 5.20 B	143.67 ± 6.81 B	D x A	ns
Total hardness (mg L^{-1} eq. $CaCO_3$)	8	163.91 ± 6.25 A	163.59 ± 4.80 A	Density	0.019
	12	172.17 ± 4.70 B	167.74 ± 4.13 B	Aeration	ns
	16	173.45 ± 4.97 B	171.85 ± 2.75 B	D x A	ns
Free CO_2 (mg L^{-1})	8	12.96 ± 2.00 A	9.92 ± 1.22 A	Density	0.003
	12	15.03 ± 1.28 B	14.45 ± 2.15 B	Aeration	ns
	16	19.40 ± 4.59 B	16.28 ± 2.49 B	D x A	ns

[1]Mean of 8 and 15h readings; [2]Non-significant (ANOVA p > 0.05). [3]For the same variable, means in the same column with different capital letters are significantly different by tukey's test (ANOVA p < 0.05); absence of letters indicates no significant differences between the mean values (p > 0.05).

Fish stocking density and afternoon aeration significantly influenced the nitrite concentrations of water (Table 2). Tanks stocked with eight fish had significantly lower NO_2^- concentrations than tanks with 12 and 16 fish. Higher loads of organic matter in the tanks with more fish produced more TAN, which is the substrate used by *Nitrosomonas* to release nitrite to water (Chen, Ling, & Blancheton, 2006). Therefore, the afternoon aeration of water could also be efficiently employed to control the concentrations of nitrite in fish tanks.

In the afternoon-aerated tanks, there was higher levels of nitrate compared to the non-aerated tanks, regardless of stocking density used ($p < 0.05$; Table 2). When the water pH exceeds 8.5, *Nitrobacter* bacteria, which are responsible for converting nitrite into nitrate, are inhibited. Possibly, the water circulation in the afternoon aerated tanks may have prevented a higher increase in the water pH in that period. If so, the biological activity of *Nitrobacter* could have been favored, increasing the concentrations of nitrate in water (Grunditz & Dalhammar, 2001).

The concentrations of reactive phosphorus in the 12 and 16 stocked tanks were almost two times higher than that observed in the 8-fish tanks ($p < 0.05$; Table 3). The feed allowances increased with the stocked biomass of fish. As the intestinal absorption of phosphorus by fish is low (≤ 25-30%), the majority of that element is lost to the water (Lazzari & Baldisseroto, 2008). The concentrations of dissolved iron (Fe^{+2}) have increased along with stocking densities, reaching values higher than 0.80 mg L-1 in the 16-fish tanks ($p < 0.05$; Table 3). Fish retain only a small portion of the iron present in the diet (Cooper, Handy, & Bury, 2006). The afternoon aeration of the water has not affected the concentrations of reactive phosphorus and dissolved iron.

Table 2. Concentrations of total ammonia nitrogen (TAN), unionized ammonia (NH_3), nitrite (NO_2^-) and nitrate (NO_3^-) in juvenile Nile tilapia tanks (body weight = 1.36 ± 0.03 g). The tanks were stocked with different fish densities and were subjected or not to afternoon aeration for eight weeks (mean ± SD).

Variable	Number of fish per tank	Water aeration		Two-way ANOVA	
		No	Afternoon	Factor	P
	8	0.93 ± 0.13 A[1]	0.91 ± 0.06 A	Density	0.001
TAN (mg L^{-1})	12	1.58 ± 0.27 Ba	1.09 ± 0.08 Bb	Aeration	0.014
	16	1.92 ± 0.14 B	1.71 ± 0.27 B	D x A	ns[3]
	8	0.29 ± 0.08 Aa	0.22 ± 0.02 Aa	Density	0.002
NH_3 (mg L^{-1})	12	0.47 ± 0.05 Ba	0.23 ± 0.01 Ab	Aeration	0.002
	16	0.48 ± 0.02 Ba	0.39 ± 0.14 Aa	D x A	ns
	8	0.34 ± 0.04 Aa	0.26 ± 0.02 Ab	Density	0.005
Nitrite (mg L^{-1})	12	0.43 ± 0.02 Ba	0.34 ± 0.02 Bb	Aeration	0.001
	16	0.41 ± 0.06 Ba	0.35 ± 0.05 Ba	D x A	ns
	8	0.96 ± 0.08 a	1.51 ± 0.09 b	Density	ns
Nitrate (mg L^{-1})	12	0.93 ± 0.06 a	1.39 ± 0.17 b	Aeration	< 0.001
	16	1.14 ± 0.21 a	1.47 ± 0.07 b	D x A	ns

[1]For the same variable, means followed by different small and capital letters in the same row and column, respectively, are significantly different by tukey's test (ANOVA $p < 0.05$); absence of letters indicates no significant differences between the mean values ($p > 0.05$); [2] Non-significant (ANOVA $p > 0.05$).

Table 3. Concentrations of reactive phosphorus, dissolved iron, total dissolved sulfide, hydrogen sulfide, and organic matter of water; soil pH and organic carbon of juvenile Nile tilapia rearing tanks (body weight = 1.36 ± 0.03 g). The tanks were stocked with different fish densities and were subjected or not to afternoon aeration for eight weeks (mean ± SD).

Variable	Number of fish per tank	Water aeration		Two-way ANOVA	
		No	Afternoon	Factor	P
	8	0.09 ± 0.01 A[1]	0.08 ± 0.03 A	Density	< 0.001
Reactive phosphorus (mg L^{-1})	12	0.20 ± 0.01 B	0.16 ± 0.01 B	Aeration	ns[3]
	16	0.16 ± 0.03 B	0.16 ± 0.04 B	D x A	ns
	8	0.48 ± 0.08 A	0.44 ± 0.01 A	Density	< 0.001
Dissolved iron (mg L^{-1})	12	0.76 ± 0.13 B	0.77 ± 0.12 B	Aeration	ns
	16	0.90 ± 0.11 C	0.87 ± 0.02 C	D x A	ns
	8	0.99 ± 0.29 A	0.93 ± 0.19 A	Density	0.028
Total dissolved sulfide (mg L^{-1})	12	1.44 ± 0.40 AB	1.31 ± 0.20 AB	Aeration	ns
	16	1.44 ± 0.29 B	1.46 ± 0.33 B	D x A	ns
	8	0.35 ± 0.10 A	0.37 ± 0.04 A	Density	0.020
Hydrogen sulfide (mg L^{-1})	12	0.50 ± 0.05 AB	0.40 ± 0.12 AB	Aeration	ns
	16	0.52 ± 0.19 B	0.54 ± 0.16 B	D x A	ns
	8	176.3 ± 7.8 A	173.3 ± 2.1 A	Density	< 0.001
Organic matter (mg L^{-1})	12	187.7 ± 10.7 B	188.3 ± 5.1 B	Aeration	ns
	16	201.3 ± 9.00 B	194.3 ± 3.5 B	D x A	ns
	8	7.16 ± 0.05	7.18 ± 0.03	Density	ns
Soil pH	12	7.12 ± 0.07	7.16 ± 0.08	Aeration	ns
	16	7.09 ± 0.08	7.10 ± 0.06	D x A	ns
	8	0.28 ± 0.03 A	0.29 ± 0.01 A	Density	0,003
Soil organic carbon (%)	12	0.34 ± 0.05 A	0.29 ± 0.02 A	Aeration	ns
	16	0.38 ± 0.02 B	0.36 ± 0.05 B	D x A	ns

[1]For the same variable, means followed by different small and capital letters in the same row and column, respectively, are significantly different by tukey's test (ANOVA $p < 0.05$); absence of letters indicates no significant differences between the mean values ($p > 0.05$); [2] Non-significant (ANOVA $p > 0.05$).

In general, the concentrations of total dissolved sulfide and hydrogen sulfide increased in the highly stocked tanks ($p < 0.05$; Table 3). The afternoon aeration was not capable to reduce those concentrations in water. This indicates that the afternoon aeration of water is a management not indicated for H2S control. The H2S usually concentrates in the water at night when the pH and water temperature are generally low (Neori & Mendola, 2012). Hence, the nocturnal aeration of water is a more appropriate management to remove H2S from the water. The concentrations of organic matter in water were significantly higher in the 12 and 16-fish tanks than in the 8-fish tanks.

Although the soil pH has not been affected by the fish stocking densities or by the afternoon aeration, the concentrations of organic carbon in the soil were lower in the tanks with lower fish biomass ($p < 0.05$). Because of its low digestibility, a great part of the artificial diet ingested by fish is lost to the culture medium as feces, which precipitate to the bottom of the tanks (Krontveit, Bendiksen, & Aunsmo, 2014).

Diel monitoring of water quality

Diel variations of water temperature, pH and dissolved oxygen (DO2) showed a similar pattern for all experimental treatments (Figures 1A, B and C).

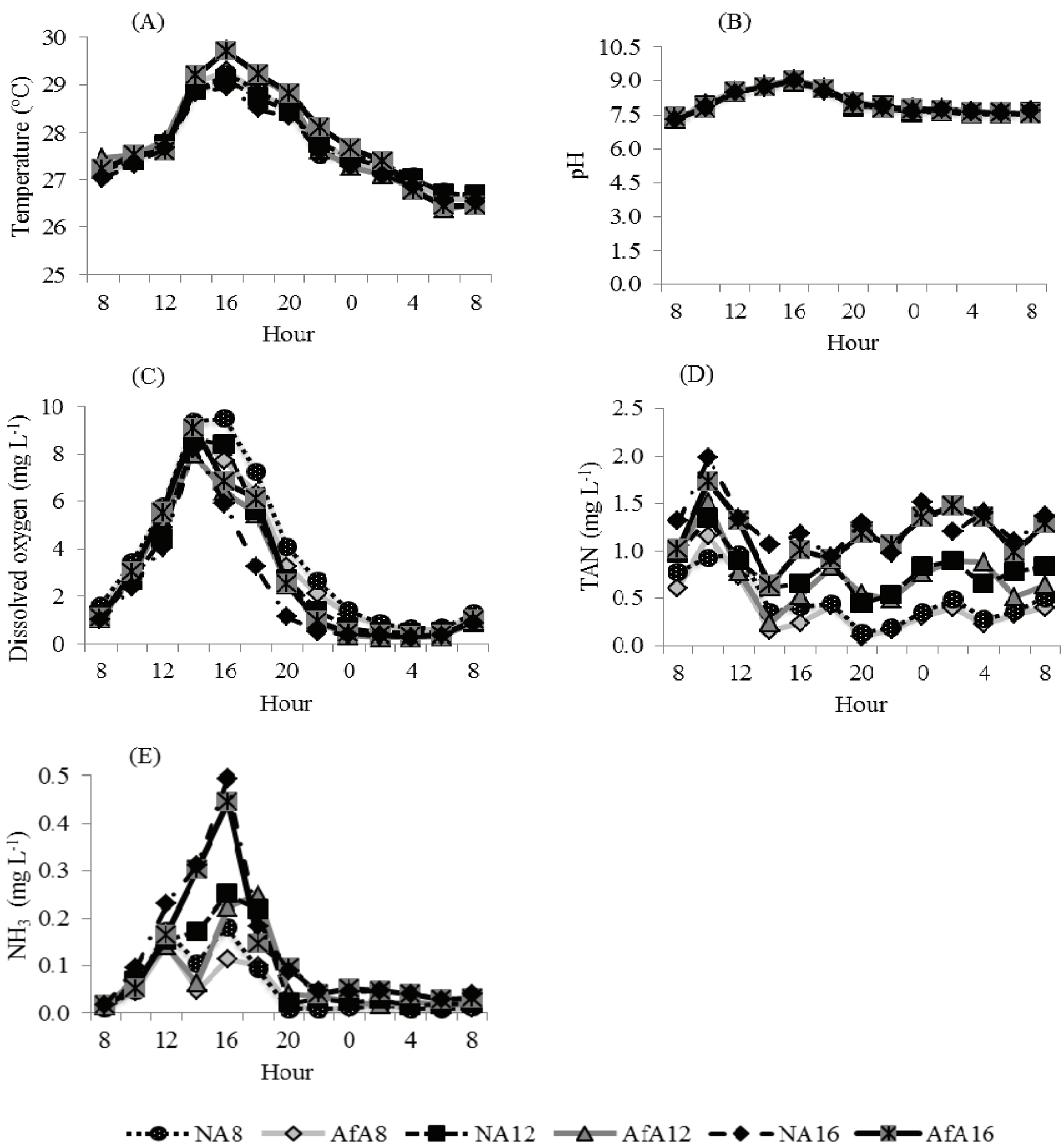

Figure 1. Diel monitoring of selected water quality variables of juvenile Nile tilapia tanks. The tanks were stocked with different fish densities and were subjected or not to afternoon aeration. NA: no aeration; AfA: afternoon aeration; 8, 12 and 16 refer to the number of fish per tank.

Figure 1 results strengthen the idea that the afternoon aeration of water is a management not appropriate for DO_2 increase. However, when photosynthesis is limited, such as on cloudy or rainy days, the farmer can turn on the aerators during the day in order to incorporate more DO_2 to the water (QAYYUM et al., 2005) or prevent water estratification (Kimpara et al., 2013a).

No clear pattern was found for the TAN diel fluctuations (Figure 1D). Except for the 16-fish tanks, the afternoon-aerated tanks showed lower concentrations of NH_3 at 14h than the non-aerated tanks. Those results demonstrate the efficiency in the NH_3 removal by the afternoon aeration. This effect was not observed in the tanks with higher fish biomass probably due to insufficient mechanical aeration provided to those tanks (Li, Li, & Wang, 2006).

Growth performance

No significant differences were detected between the experimental treatments for fish survival, which was high in all tanks (> 80 %; Table 4).

Fish growth performance was significantly affected only by the "stocking density" factor. Therefore, the afternoon aeration of water has not affected the tilapia growth performance (Table 4). In general, except for results of fish productivity, the variables of growth performance were impaired with the increase in fish stocking density. Usually, the relationship between the individual body weight and fish productivity (total biomass) is inverse. The optimum combination between the indiviaul body weight and the total stocked biomass only achieved when the productive system is working at the limit of the its carrying capacity (Stigebrandt, 2011). The highest fish stocking density employed in the present work, i.e., 16 fish tank^{-1}, probably exceeded the carrying capacity of the lab's rearing system. Furthermore, it is speculated that the differences between the treatments for fish growth performance would have been even greater if another fish species, not as rustic as Nile tilapia, had been used as a biological model.

Tank effluent quality

The factor "fish stocking density" was the only one that significantly affected the quality of the tank effluents (Figure 2). Therefore, the afternoon aeration has not significantly affected the effluent quality. These results suggest that the afternoon aeration is a management more important to the culture water than to the effluent quality. Probably, the nocturnal aeration brings greater benefits to the tank effluent quality than the afternoon aeration.

The pH of the tank effluents was above 8 in all treatments, without significant differences between themselves (Figure 2A). The DO2 concentratigons in the tank effluents were below 2 mg L^{-1} in all tanks. The DO_2 concentrations in the 8-fish tanks were higher than those in the 12 and 16-fish tanks ($p < 0.05$; Figure 2B).

Table 4. Growth performance of juvenile Nile tilapia (body weight = 1.36 ± 0.03 g) stocked for eight weeks in outdoor tanks at different stocking densities and subjected or not to afternoon aeration (mean ± SD).

Variable	Number of fish per tank	Water aeration		Two-way ANOVA	
		None	Afternoon	Factor	P
Survival (%)	8	87.5 ± 12.50	95.83 ± 4.17	Density	ns[4]
	12	83.33 ± 8.33	83.33 ± 8.33	Aeration	ns
	16	83.33 ± 3.61	83.33 ± 3.61	D x A	ns
Final body weight (g)	8	22.80 ± 2.25 A[5]	21.92 ± 1.29 A	Density	<0.001
	12	20.18 ± 2.52 A	23.18 ± 0.79 A	Aeration	ns
	16	17.27 ± 0.36 B	18.30 ± 0.27 B	D x A	ns
SGR[1] (% day^{-1})	8	5.06 ± 0.16 A	5.04 ± 0.10 A	Density	<0.001
	12	4.78 ± 0.25 A	5.02 ± 0.04 A	Aeration	ns
	16	4.57 ± 0,03 B	4.60 ± 0.01 B	D x A	ns
Weekly weight gain (g)	8	2.15 ± 0.22 A	2.05 ± 0.13 A	Density	<0.001
	12	1.88 ± 0.25 A	2.18 ± 0.08 A	Aeration	ns
	16	1.59 ± 0.03 B	1.69 ± 0.03 B	D x A	ns
Fish productivity (g m^{-3} day^{-1})	8	9.04 ± 0.41 A	9.16 ± 0.16 A	Density	<0.001
	12	11.60 ± 2.31 B	13.24 ± 1.19 B	Aeration	ns
	16	13.16 ± 0.67 B	12.20 ± 0.45 B	D x A	ns
FCR[2]	8	0.79 ± 0.01 A	0.82 ± 0.01 A	Density	<0.001
	12	0.90 ± 0.07 A	0.82 ± 0.06 A	Aeration	ns
	16	1.09 ± 0.03 B	1.03 ± 0.06 B	D x A.	ns
PER[3]	8	2,89 ± 0,03 A	2,78 ± 0.03 A	Density	<0.001
	12	2.54 ± 0.20 A	2.81 ± 0.22 A	Aeration	ns
	16	2.10 ± 0.05 B	2.21 ± 0.12 B	D x A	ns

[1]Specific growth rate (SGR) = [(Ln final weight - Ln initial weight) number of days^{-1}] x 100; [2] feed conversion ratio (FCR) = feed allowance (g) fish weight gain^{-1} (g); [3] Protein efficiency ratio (PER) = weight gain (g) protein consumed^{-1} (g); [4] Non-significant (ANOVA p > 0.05). [5] For the same variable, means followed by different capital letters in the same column are significantly different by tukey's test (ANOVA p < 0.05); absence of letters indicates no significant differences between the mean values (p > 0.05).

The concentrations of TAN in the tank effluents increased progressively with the stocking densities (Figure 2C). Similarly, the NH_3 concentrations in the effluents were higher in the tanks with more fish and there was a significant difference between the 8 and 16-fish tanks for NH_3 (Figure 2D). The concentrations of nitrite in the tank effluents were higher ($p < 0.05$) in the 16-fish tanks when compared to the 8 and 12-fish tanks (Figure 2E). The concentrations of reactive phosphorus were not significantly different between the 12 and 16-fish tanks, but were higher than in the 8-fish tanks ($p < 0.05$; Figure 2F). Therefore, the increase in fish stocking density has led to effluents with less oxygen and higher concentrations of ammonia, nitrite and phosphorus (KIMPARA et al., 2013b).

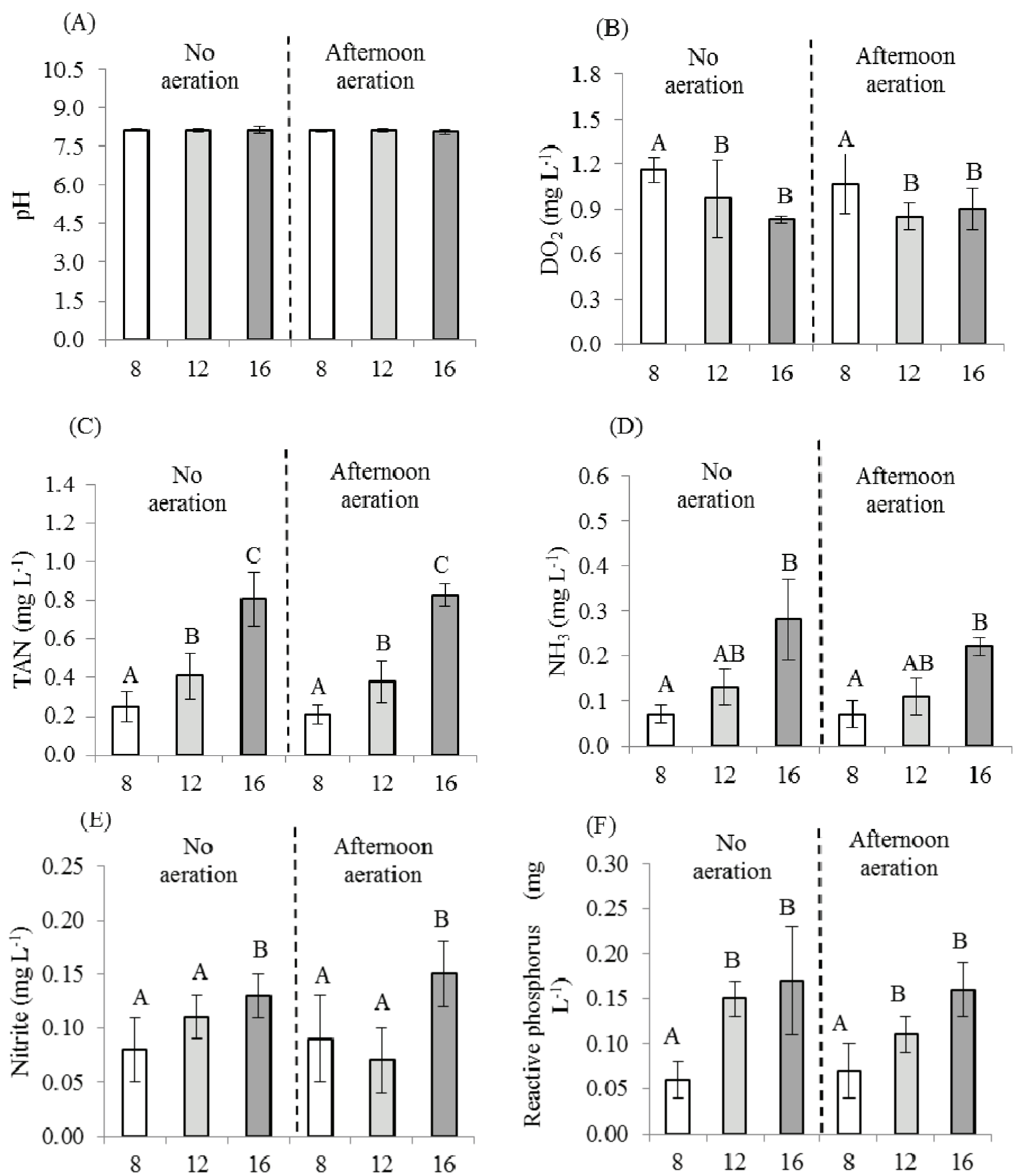

Figure 2. Quality of Nile tilapia tank effluents 48 hours after the final harvest. The rearing tanks were subjected or not to afternoon aeration for eight weeks. The afternoon aeration has not significantly affected any of these variables ($p > 0.05$). Numbers 8, 12 and 16 refer to the number of fish per tank.

Conclusion

The afternoon aeration of water is an efficient management to remove gaseous ammonia (NH_3) and nitrite from fish tanks. The NH_3 removal will be more effective in more intensive farming systems, in which the stocked fish biomass is high. The rate of the afternoon aeration of water should be proportional to the fish stocking density to obtain the desired results.

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