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# Growth performance of Nile tilapia, *Oreochromis niloticus*, fingerlings reared in $Na_2CO_3$ limed waters

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**ABSTRACT.** Current experiment was undertaken during 6 weeks with Nile tilapia, *Oreochomis niloticus*, fingerlings (1.28 ± 0.03 g) to assess the effects of moderate $Na_2CO_3$ liming on water quality and fish growth performance. Twenty-four 25 L-aquaria, with 15 fish per aquarium, were used, of which twelve aquaria were placed in the lab's indoor room and twelve in the outdoor area. Two types of water (clear or green) and three different water-quality managements (none, HCl acidification and $Na_2CO_3$ liming) were simultaneously evaluated in a 3 x 2 factorial design. Total ammonia, calcium hardness, pH and total alkalinity in the green water aquaria were significantly higher than rates in the clear water aquaria. Slight liming acid water with $Na_2CO_3$ did not produce any significant effect on its water calcium hardness. No significant differences between controls and the experimental group were observed for any growth variables. Lime rearing water with $Na_2CO_3$ has no significant effect on tilapia growth performance if the initial total alkalinity of water is higher than 20 mg $CaCO_3$ $L^{-1}$.

**Key words:** fish culture, limnology, water alkalinity, water hardness.

**RESUMO. Desempenho produtivo de alevinos de tilápia nilótica, *Oreochromis niloticus*, em aquários submetidos à calagem com $Na_2CO_3$.** O presente estudo foi realizado por seis semanas com alevinos de tilápia do Nilo, *Oreochromis niloticus* (1,28 ± 0,03 g), para avaliar os efeitos da calagem moderada da água de cultivo com $Na_2CO_3$ na qualidade da água e no desempenho produtivo dos peixes cultivados. Vinte e quatro aquários de polietileno de 25 L foram utilizados para manter os peixes experimentais (15 peixes por aquário). Doze aquários foram instalados na sala interna do laboratório e 12 aquários na área externa. Dois tipos de águas (claras, sem fitoplâncton ou verdes, ricas em fitoplâncton) e três diferentes manejos de qualidade de água (nenhum, acidificação com HCl ou calagem com $Na_2CO_3$) foram avaliados simultaneamente em delineamento fatorial 3 x 2. A concentração de amônia total, dureza cálcica, pH e alcalinidade total das águas verdes foram significativamente maiores que para as águas claras. A calagem das águas fracamente ácidas com $Na_2CO_3$ não produziu nenhum efeito significativo na dureza cálcica da água. Não se observaram diferenças significativas entre os grupos-controle e o grupo experimental para nenhuma das variáveis de desempenho produtivo observadas. Concluiu-se que fazer a calagem da água de cultivo de tilápias com $Na_2CO_3$ não trará nenhum benefício ao desempenho zootécnico dos peixes se a alcalinidade inicial da água exceder 20 mg $L^{-1}$ de $CaCO_3$.

**Palavras-chave:** piscicultura, limnologia, alcalinidade, dureza.

## Introduction

Since the analysis of ponds' and tanks' water quality is important to maintain fish health and growth, fish breeders should have basic information on dissolved oxygen, pH and ammonia so that their rearing units could be better managed. Alkalinity and hardness are two water quality indicators that deserve the attention of fish breeders (GOMES; SILVA, 2009). Total water alkalinity refers to its bicarbonate and carbonate contents which are the anions responsible for the water's pH buffer system. Total hardness indicates the amount of calcium and magnesium, which are minerals required for the normal metabolism of aquatic life (BOYD, 2000).

In shallow water exchange units, liming may be successfully carried out to increase water pH, alkalinity and hardness (BOYD et al., 2007). Rojas and Rocha (2004) found that post-larvae (0.03 ± 0.007 g) of the Nile tilapia, *Oreochromis niloticus*, grew significantly bigger when total alkalinity of culture water was 30 mg $CaCO_3$ $L^{-1}$. Fish maintained in waters with total alkalinity of 15 or 60 mg $CaCO_3$ $L^{-1}$

had growth impairment. According to these authors, the culture water with total alkalinity, soluble calcium, total hardness and pH of 60 mg $CaCO_3$ $L^{-1}$, 25 mg $L^{-1}$, 70 mg $CaCO_3$ $L^{-1}$ and 7.9, respectively, compromised significantly post-larvae growth. These values, however, are within the adequate ranges for tropical fish culture (BOYD; TUCKER, 1998).

Recently, however, Cavalcante et al. (2009) have found that the application of analytical calcium carbonate at 1 g 10 $L^{-1}$ in clear or green rearing waters produced bigger Nile tilapia body weight. The above-mentioned study concluded that pH: 7.4 – 8.2; total alkalinity > 50 mg $CaCO_3$ $L^{-1}$; calcium hardness > 140 mg $CaCO_3$ $L^{-1}$ and free $CO_2$ < 7 mg $L^{-1}$ was the best set of limnological conditions that improved Nile tilapia growth. Therefore, divergence exists between the results obtained by Rojas and Rocha (2004) and those by Cavalcante et al. (2009). It seems that post-larvae of Nile tilapia are not only more susceptible to changes in the acid-basis equilibrium of water than older juveniles, but they prefer more acid conditions.

Further, since Rojas and Rocha (2004) have applied calcium carbonate in aquaria which simultaneously increased water alkalinity and hardness, it may be inquired which factor, whether alkalinity, or hardness or both, improved or impaired tilapia growth. For a better understanding of the issue, current investigation was undertaken with juvenile Nile tilapia, *O. niloticus*, to assess the effects of moderate sodium carbonate ($Na_2CO_3$) liming on water quality and fish growth performance. When $Na_2CO_3$ is used to lime fish culture water, only its alkalinity is increased, with no effect on its hardness.

## Material and methods

Five hundred male sex-reversed fingerlings (0.96 ± 0.01 g) of Nile tilapia, *Oreochromis niloticus*, were obtained from the Research Center in Aquaculture of the Brazilian Department in Public Works against Droughts [Centro de Pesquisas em Aqüicultura of the Departamento Nacional de Obras Contra as Secas – DNOCS], in Pentecoste, Ceará State, Brazil. Fish were transported to the Laboratory of Aquiculture Science and Technology [Laboratório de Ciência e Tecnologia Aquícola – LCTA] of the Department of Fishing Engineering, Center for Agrarian Sciences of the Universidade Federal do Ceará, Fortaleza, Ceará State, Brazil. Fish were transferred to a 1000-L fiberglass aerated (reception) tank at the laboratory.

Fish were kept in the reception tank for a week to acclimatize themselves to laboratory conditions. Forty-eight hours after stocking, fish were treated with analytical grade potassium permanganate at 4 mg $L^{-1}$ for 48 hours to prevent bacterial infestation. After this period, analytical grade sodium thiosulphate, 4 mg $L^{-1}$, was used to neutralize the residual effect of potassium permanganate (DARWISH et al., 2009). During the acclimatization period, fish were fed a high-protein commercial diet (Fri-Acqua 56, Rações Fri-Ribe S.A., Maracanaú, Ceará State) in four daily meals at 8 a.m., 11 a.m., 2 p.m. and 5 p.m. The commercial diet used had an average particle size of 0.8 mm, whereas daily feeding rate amounted to 10% of the stocked biomass.

Twenty-four 25 L-polyethylene aquaria were used to keep the experimental fish. Twelve aquaria were set in the LCTA's indoor room and twelve aquaria in its outdoor area. Whereas in the indoor room top-roofed fluorescent lights were used (10h light: 14h darkness) with very little sunlight, the outdoor area exposed the aquaria directly to sunlight (natural daylight). The optical transmittance of the culture water at 670 nm was recorded to estimate the phytoplankton density in the aquaria (SUN et al., 2009). The experimental aquaria were provided by continuous aeration and equipped with a cotton mesh cover to prevent escape of fish. At the onset of the experiment, fifteen fingerlings (1.28 ± 0.03 g) were stocked in each 25 L-polyethylene aquarium. Pooled fish body weight and total body length of ten individuals were registered for each aquarium. During the first week, dead fish found in the aquaria were removed and substituted by others from the reception tank, with the same body weight and length. Fish were maintained in the experimental systems for 6 weeks.

Two experimental factors were evaluated simultaneously in a completely randomized 3 x 2 factorial design, or rather, two types of culture water and three different water quality managements. Aquaria with clear or green water underwent one of the following water managements: none (positive control), acidification with concentrated HCl a 1 mL 20 $L^{-1}$ (negative control) or liming with analytical grade $Na_2CO_3$ at 1 g 10 $L^{-1}$ (experimental group). Therefore, six different experimental conditions were set up: (1) clear water and no water management; (2) clear water and water acidification with HCl; (3) clear water and water liming with $Na_2CO_3$; (4) green water and no water management; (5) green water and water acidification with HCl; and (6) green water and water liming with $Na_2CO_3$. Each control or treatment received four replicates.

After its residual chlorine had been removed by aeration and resting, tap water was used to fill the aquaria. The water was maintained clear in the indoor aquaria (without phytoplankton) and became green in the outdoor aquaria (with phytoplankton). Although no fertilization occurred in the outdoor tanks, good phytoplankton growth was indirectly produced by feeding fish with the commercial diet (water's optical transmittance at 670 nm lower than 80%). The physical and chemical characteristics of the supply water were the followings: total alkalinity = 56.5 ± 2.43 mg $CaCO_3$ $L^{-1}$, calcium hardness = 63.3 ± 2.42 mg $CaCO_3$ $L^{-1}$, pH = 7.4 ± 0.1 and free $CO_2$ = 6.2 ± 1.6 mg $L^{-1}$ (mean ± s.d; n = 3). Five days after HCl acidification or $Na_2CO_3$ liming, the variables were respectively changed as follows: total alkalinity = 21.23 ± 1.63 and 78.0 ± 2.28 mg $CaCO_3$ $L^{-1}$, calcium hardness = 60.3 ± 2.34 and 63.7 ± 2.94 mg $CaCO_3$ $L^{-1}$, pH = 6.1 ± 0.1 and 8.2 ± 0.1 and free $CO_2$ = 18.7 ± 1.8 and 1.0 ± 2.4 mg $L^{-1}$.

Initially, all aquaria were filled with dechlorinated tap water. In the second, third and fourth days, the water of aquaria was replaced by acidified or limed water at 1/3, 2/3 and 3/3. From the fourth day till the end of the experiment, weekly exchanges of water were carried out at 2/3 in order to maintain the experimental water's designed physical and chemical characteristics.

A single phytoplankton inoculation was undertaken in all aquaria. Fifty milliliters of dark green water from the fish tanks of a nearby fish culture station were poured into the aquaria water on the $5^{th}$ day of the experiment. The outdoor waters developed a strong green color just four days after inoculation, whereas no significant phytoplankton grew in the indoor aquaria (water's optical transmittance at 670 nm > 90%).

All stocked fish were fed with the same commercial diet used during the acclimatization period. Fish received three meals a day, at 8 a.m, noon and 4 p.m. The feeding rates employed were 10, 8 and 6% of the stocked biomass on weeks 1-2, 3-4 and 5-6, respectively. The amount of feed for each aquarium was adjusted fortnightly after taking fish weight.

Water pH, total alkalinity, calcium hardness, free $CO_2$ and total ammonia were monitored weekly in all aquaria. Further, total alkalinity and free $CO_2$ concentration of water were recorded hour by hour, from 8 a.m. to 6 p.m. Water pH was measured by a portable pH meter (Marconi PA 200) and water temperature registered by a digital thermometer. The analytical determinations of total alkalinity, calcium hardness, free $CO_2$ and total ammonia were carried out according to APHA guidelines (APHA, 1999). A 500 mL-water sample was withdrawn weekly from each aquarium for limnological analyses. Final fish body weight, length and biomass, weekly weigh gain, survival and feed conversion rate were reported for all experimental aquaria.

Water temperature varied during the day in the outdoor system. In the hour by hour temperature monitoring from 8 a.m. to 6 p.m, the water temperature ranged from below 27°C up to more than 35°C in the outdoor aquaria. Whereas outdoor water temperature averaged 29.9 ± 3.28°C (n = 240; no night readings were carried out), the water temperature in the indoor tanks was more stable during the day, ranging from approximately 27°C at 8 a.m. to 28°C at 4 p.m. The indoor water temperature averaged 28.0 ± 0.69°C (n = 240; no night readings were carried out).

The optical transmittance of water samples at 670 nm was observed in order to estimate algal turbidity. As expected, the outdoor aquaria water had significantly lower optical transmittance than the indoor aquaria water (75.5 ± 0.48% x 94.0 ± 0.14%, respectively). No significant differences were reported between the optical transmittance of controls (non-managed or acidified aquaria) and the experimental ($Na_2CO_3$ limed aquaria) group, for clear and green water systems.

Water quality and growth performance results were submitted to two-way ANOVA to detect whether there were significant differences between controls and the experimental group. Tukey's test compared means in pairs when differences were significant. The statistical analyses were performed with SigmaStat 2.0 software (Jandel Corporation, San Rafael CA, USA). A 5% significance level was adopted in all statistical analyses.

## Results and discussion

Total ammonia, calcium hardness, pH and total alkalinity rates in the green water aquaria were significantly higher than those in the clear water aquaria. Except for the aquaria with $Na_2CO_3$ liming, the concentration of free $CO_2$ in the green waters was significantly lower than that in the clear water (Table 1; $p < 0.05$).

Higher total ammonia in the outdoor green water aquaria was due to their increased amount of living or dead biomass when compared with that of the clear water aquaria. The outdoor aquaria had also plenty of phytoplankton besides fish. More biomass and organic detritus generally means more ammonia, since there is more protein to be decomposed for ammonia production (PORRELLO et al., 2003).

**Table 1.** Water quality variables monitored weekly or daily (pH) in 25 L-polyethylene aquaria stocked with fifteen fingerlings (1.28 ± 0.03 g) of Nile tilapia, *Oreochromis niloticus*, and submitted to different managements (mean ± s.d.; n = 4). Results for total alkalinity and calcium hardness are in mg $CaCO_3$ $L^{-1}$; the results for free $CO_2$ and total ammonia are in mg $L^{-1}$.

| Water | Management | | |
|---|---|---|---|
| | None | HCl acidification[1] | $Na_2CO_3$ liming[2] |
| pH | | | |
| Clear | 6.58 ± 0.10 Bb[3] | 6.18 ± 0.10 Ac | 7.40 ± 0.22 Ba |
| Green | 7.13 ± 0.05 Ab | 6.40 ± 0.08 Ac | 8.03 ± 0.10 Aa |
| Total alkalinity | | | |
| Clear | 47.15 ± 0.87 Bb | 22.48 ± 1.86 Bc | 68.55 ± 3.25 Ba |
| Green | 57.78 ± 0.84 Ab | 28.30 ± 0.29 Ac | 80.60 ± 1.26 Aa |
| Calcium hardness | | | |
| Clear | 81.93 ± 1.22 B | 79.43 ± 1.06 B | 82.85 ± 0.70 B |
| Green | 95.35 ± 2.24 A | 94.73 ± 1.26 A | 95.68 ± 1.42 A |
| Free $CO_2$ | | | |
| Clear | 20.8 ± 0.98 Ab | 29.6 ± 2.26 Aa | 12.4 ± 1.26 Ac |
| Green | 16.0 ± 1.18 Bb | 23.3 ± 1.24 Ba | 12.3 ± 0.54 Ac |
| Total ammonia | | | |
| Clear | 0.44 ± 0.05 B | 0.51 ± 0.07 B | 0.50 ± 0.06 B |
| Green | 0.82 ± 0.08 A | 0.83 ± 0.07 A | 0.76 ± 0.08 A |

*Two-way ANOVA*

| | pH | Total alkalinity | Calcium hardness | Free $CO_2$ | Total ammonia |
|---|---|---|---|---|---|
| Water type | < 0.001 | < 0.001 | < 0.001 | < 0.001 | < 0.001 |
| Management | < 0.001 | < 0.001 | ns | < 0.001 | Ns |
| Interaction | 0.007 | ns[4] | ns | < 0.001 | Ns |

[1]Acidification of supply water with concentrated analytical grade HCl at 1.0 mL 20 $L^{-1}$; [2]Liming of acidified water with analytical grade $Na_2CO_3$ at 1 g 10 $L^{-1}$; [3]For each variable, means with different capital letters in a column or with small letters in a row are significantly different among themselves by Tukey's test ($p < 0.05$). Means lack significance when no letter is shown; [4]Not significant ($p > 0.05$).

During the day pH increases in green water due to the photosynthesis which consumes $CO_2$. Less $CO_2$ in water means less carbonic acid which is produced when $CO_2$ reacts with the water molecule. The withdrawal of $CO_2$ by microalgae turns $HCO_3^-$ (bicarbonate) and $CO_3^{-2}$ (carbonate) ions into the major forms of inorganic carbon in water and increases its alkalinity (PAGAND et al., 2000). This effect has been confirmed when an hour by hour monitoring of water total alkalinity and $CO_2$ concentration was undertaken (Figure 1).

Liming acidic water with $Na_2CO_3$ increases its pH according to the following reaction: $Na_2CO_3 + CO_2 + H_2O \rightarrow 2NaHCO_3$ (BOYD; TUCKER, 1998). Therefore, the effect of $Na_2CO_3$ on $CO_2$ withdrawal triggers a higher water pH, as previously discussed.

Results of total ammonia and algal density (water transparency) in clear and green water systems were not significantly different from those between the experimental group (limed aquaria) and controls (non-managed or acidified aquaria; Table 1). These results indicate that the water acidification carried out in current experiment was weak and the supply water had a suitable total alkalinity (56.6 mg $CaCO_3$ $L^{-1}$). Thus, current results corroborate those by Soderberg et al. (2000) who state that no advantage to water quality is registered when its total alkalinity is equal or higher than 20 mg $CaCO_3$ $L^{-1}$.

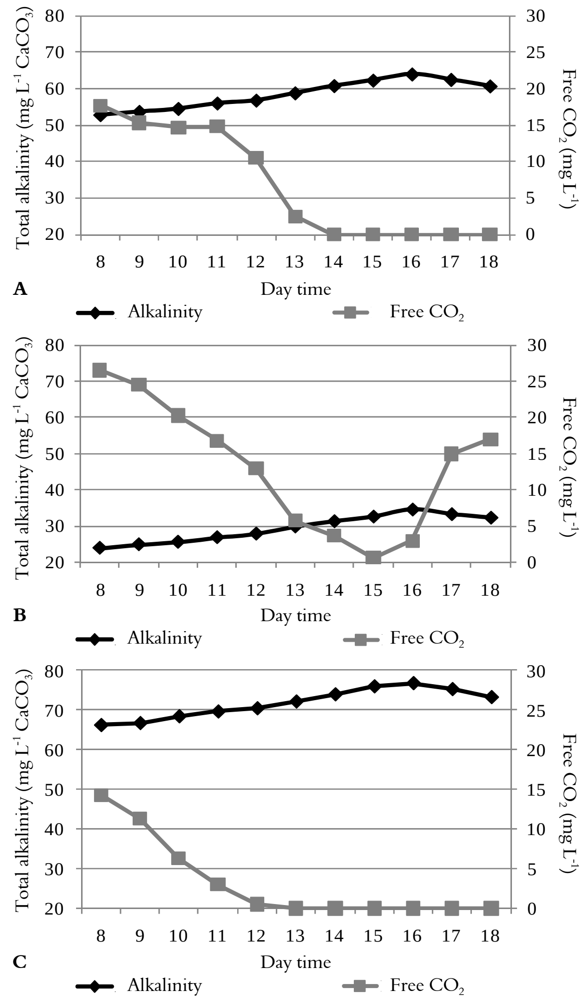


**Figure 1.** Relationship between the total alkalinity and free $CO_2$ concentration of water during the day in outdoor 25 L aquaria submitted to different water quality managements. A: no water management; B: application of concentrated HCl at 1 mL 20 $L^{-1}$; C: liming of acidified water with analytical $Na_2CO_3$ at 1 g 10 $L^{-1}$.

Liming weak acid waters with $Na_2CO_3$ did not produce any significant effect on its water calcium hardness. On the other hand, total alkalinity of the acidified water was significantly lower than that reported for the limed water (Table 1). Since this was true both for the clear and green waters, results suggest that natural or artificial processes capable of acidifying water do not affect water hardness, although they decrease significantly its total alkalinity.

Cavalcante et al. (2009) reported that rates of total alkalinity of green waters of non-managed aquaria and $CaCO_3$ liming aquaria were not significantly different among themselves. In current experiment, the application rate of $CaCO_3$ was the same as that in current experiment, i.e., 1 g 10 $L^{-1}$. Conversely, when $Na_2CO_3$ was used to lime green waters in current experiment, total alkalinity of water of limed aquaria was significantly higher than that verified in the non-managed aquaria (Table 1). These results suggest that $Na_2CO_3$ has a stronger capacity to increase water alkalinity than $CaCO_3$. This feature is probably due to higher water solubility of $Na_2CO_3$ when compared to that of $CaCO_3$. It seems that $Na_2CO_3$ is a better product than $CaCO_3$ to lime fish culture tanks because it increases more effectively water alkalinity.

Final body weight, weigh gain and final biomass of fish reared in indoor clear waters were significantly higher than rates in outdoor green waters. Besides, food conversion ratio (FCR) of the fish reared in the indoor system was significantly lower than ratio for the outdoor system (Table 2; $p < 0.05$). No significant difference was detected between the two rearing systems for fish survival and final body length. LCTA's outdoor culture system has actually tougher environmental conditions than those of the indoor culture system. The outdoor aquaria in current experiment presented higher concentrations of total ammonia and wider variations of water temperature and pH throughout the day than those reported for indoor aquaria. On certain days, water temperature and pH in the outdoor aquaria exceeded 35°C and 9.5, respectively. These facts stressed the outdoor cultured fish and impeded their growth and FCR.

Within the same water type, i.e., clear or green, no significant differences were reported between control groups (non-managed or acidified aquaria) and the experimental group ($Na_2CO_3$ limed aquaria) for any growth performance variables monitored in the present research (Table 2). Although total alkalinity rates in clear and green water in the limed aquaria (68.55 ± 3.25 and 80.60 ± 1.26 mg $CaCO_3$ $L^{-1}$, respectively) were higher than those for the non-managed aquaria (47.15 ± 0.87 and 57.78 ± 0.84 mg $CaCO_3$ $L^{-1}$, respectively); and although the latter rates were higher than those registered for acidified aquaria (22.48 ± 1.86 and 28.30 ± 0.29 mg $CaCO_3$ $L^{-1}$, respectively), no significant effect was observed in fish growth or survival between the aquaria. In fact, the lowest rates of water alkalinity reported in current experiment were still higher than 20 mg $CaCO_3$ $L^{-1}$, considered the minimum value suitable for fish growth (BOYD; TUCKER, 1998). Therefore, water acidification management accomplished in current research failed to affect negatively fish development. Thus, no benefit to fish growth performance may be foreseen when liming occurs in water with total alkalinity higher than 20 mg $CaCO_3$ $L^{-1}$.

**Table 2.** Growth performance of fingerlings (1.28 ± 0.03 g and 4.13 ± 0.16 cm) of Nile tilapia, *Oreochromis niloticus*, stocked for 6 weeks in 25 L-polyethylene aquaria with different water quality managements. Results of final body weight, weigh gain, final total body length, final biomass and survival are in g $fish^{-1}$, g $week^{-1}$, cm $fish^{-1}$, g $aquarium^{-1}$ and %, respectively (mean ± s.d.; n = 4).

| Water | Management | | |
|---|---|---|---|
| | None | HCl acidification[1] | $Na_2CO_3$ liming[2] |
| Final body weight | | | |
| Clear | 4.78 ± 0.17 A[3] | 4.52 ± 0.33 A | 4.94 ± 0.52 A |
| Green | 3.79 ± 0.29 B | 4.18 ± 0.31 B | 4.16 ± 0.41 B |
| Weight gain | | | |
| Clear | 0.59 ± 0.03 A | 0.55 ± 0.05 A | 0.60 ± 0.09 A |
| Green | 0.42 ± 0.05 B | 0.48 ± 0.05 B | 0.48 ± 0.06 B |
| Final body length | | | |
| Clear | 6.93 ± 0.33 | 7.10 ± 0.13 | 6.94 ± 0.42 |
| Green | 6.81 ± 0.22 | 6.83 ± 0.28 | 7.02 ± 0.21 |
| Final biomass | | | |
| Clear | 64.52 ± 5.94 A | 64.31 ± 2.94 A | 66.65 ± 7.55 A |
| Green | 56.06 ± 5.94 B | 57.27 ± 0.69 B | 60.18 ± 3.76 B |
| Survival | | | |
| Clear | 90.0 ± 6.7 | 95.0 ± 3.3 | 90.0 ± 3.8 |
| Green | 98.3 ± 3.3 | 91.7 ± 6.4 | 96.7 ± 3.9 |
| FCR | | | |
| Clear | 2.34 ± 0.27 A | 2.42 ± 0.18 A | 2.20 ± 0.10 A |
| Green | 2.66 ± 0.36 B | 2.61 ± 0.06 B | 2.52 ± 0.31 B |

| *Two-way ANOVA* | Body weight | Weight gain | Body length | Biomass | Survival | FCR |
|---|---|---|---|---|---|---|
| Water type | < 0.001 | < 0.001 | ns | 0.002 | ns | 0.012 |
| Management | ns[4] | ns | ns | ns | ns | ns |
| Interaction | ns | ns | ns | ns | ns | ns |

[1]Acidification of water supply with concentrated analytical grade HCl at 1.0 mL 20 $L^{-1}$; [2]Liming of acidified water with analytical grade $Na_2CO_3$ at 1 g 10 $L^{-1}$; [3]Means for each variable with different capital letters in column or with small letters in row are significantly different among themselves by Tukey's test ($p < 0.05$). Means lack significance when no letter is shown; [4]Not significant ($p > 0.05$)

In a study with the silver catfish, *Rhamdia quelen*, Andrade et al. (2007) observed a significant interaction between the stocking density of fish and total water alkalinity. Fish stocked at higher densities showed a better survival rate when total water alkalinity was increased from 30 to 80 or 130 mg $CaCO_3$ $L^{-1}$.

In spite of free $CO_2$ concentrations in $Na_2CO_3$-limed aquaria rates have been significantly lower than those in the non-managed ones, the latter have been lower than those found in the acidified aquaria. These facts have not significantly affected fish growth. Results of current experiment suggest that tilapia fingerlings tolerated satisfactorily the moderately high levels of free $CO_2$. Concentrations of free $CO_2$ in water as high as 29.6 mg $L^{-1}$ were registered in the present trial. Nevertheless, it is noteworthy that a constant supply of forced air was delivered to all aquaria. Free $CO_2$ in water, even when in high concentrations, seems to be harmless to fish when there are suitable concentrations of dissolved oxygen in water. This fact, however, is rarely observed in commercial tanks or ponds (HARGREAVES et al., 2000). Therefore, it may be assumed that fish growth performance in present research would have been significantly affected by the concentrations of free $CO_2$ in water if there were no extra source of dissolved oxygen in the water.

While no significant effect of $Na_2CO_3$ liming on fish growth performance was reported in current experiment, Cavalcante et al. (2009) detected a significantly better fish growth performance when the animals were maintained in $CaCO_3$-limed aquaria. These results suggest that a simultaneous increase in water hardness and alkalinity, as warranted by the application of $CaCO_3$, produces a better fish growth performance than that reported when only water alkalinity is increased. This is especially true if total water alkalinity is higher than 20 mg $L^{-1}$ $CaCO_3$ eq. as has been the case in current experiment.

## Conclusion

Lime tilapia's culture water with $Na_2CO_3$ has no significant effect on fish growth performance if the initial total water alkalinity is higher than 20 mg $CaCO_3$ $L^{-1}$.

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