CALCIUM SILICATE AND SOIL IN THE INTENSIVE CULTIVATION OF NILE TILAPIA

SILICATO DE CÁLCIO E SOLO NO CULTIVO INTENSIVO DE TILÁPIA-DO-NILO

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ABSTRACT

This study aimed to analyze the calcium silicate and soil, comparing them to conventional liming products and verifying their effects on the stability of the environment and development of tilapia juveniles. For 60 days, juveniles were cultivated under five conditions, namely: Control - aquarium containing only water; Calcites – water and calcium carbonate – $CaCO_3$; Dolomitic - water and dolomitic limestone - 70% $CaCO_3$• 30% $MgCO_3$; Soil – aquarium with soil at the bottom and Silicate – water and calcium silicate – Ca_2SiO_4 (3 g of salts L^{-1}), with five repetitions each. The measured parameters were conductivity, pH, redox potential, salinity, turbidity, ammonia, nitrite, nitrate, alkalinity, hardness, calcium, magnesium, silica, weight, standard length, total length, biomass, and survival. From the records, weight gain, biomass gain, feed conversion ratio, and Fulton's condition factor were calculated. The calcium silicate presented better results (total length and weight gain) than those observed in the soil, and equivalents (survival, individual consumption, weight, weight gain, biomass, standard and total lengths, and feed conversion) to calcitic and dolomite limestone. The pH presented better results for the silicate and was similar to the calcitic treatment, which did not differ from the dolomite. Alkalinity and silica had higher values in the silicate. Hardness and calcium presented higher values in the silicate and in the calcitic treatments when compared to the control and the soil. Calcium silicate is a viable and recommended alternative liming in the intensive cultivation of juvenile Nile tilapia. He presented results equivalent to calcitic and dolomitic limestones, traditional salts for this practice. Calcitic and dolomitic limestones proved to be efficient in the liming process, in the intensive system. The use of soil as a liming material did not show promising results. However, it, like other products, should be better evaluated.

KEYWORD: alkalinity; liming; hardness; pH; water quality.

RESUMO

Este estudo teve como objetivo analisar o silicato de cálcio e o solo, comparando-os aos produtos de calagem convencional e verificando seus efeitos na estabilidade do ambiente e no desenvolvimento de juvenis de tilápia. Durante 60 dias, os juvenis foram cultivados em cinco condições, a saber: Controle - aquário contendo apenas água; Calcítico – água e carbonato de cálcio – $CaCO_3$; Dolomítico - água e calcário dolomítico - 70% $CaCO_3$• 30% $MgCO_3$; Solo – aquário com terra no fundo e Silicato – água e silicato de cálcio – Ca_2SiO_4, (3 g de sais L^{-1}), com cinco repetições cada. Os parâmetros medidos foram: condutividade, pH, potencial redox, salinidade, turbidez, amônia, nitrito, nitrato, alcalinidade, dureza, cálcio, magnésio, sílica, peso, comprimento padrão, comprimento total, biomassa e sobrevivência. A partir dos registros foram calculados ganho de peso, ganho de biomassa, conversão alimentar e fator de condição de Fulton. O silicato de cálcio apresentou melhores resultados (consumo, comprimento total e ganho de peso) que os observados no solo, e equivalentes (sobrevivência, consumo individual, peso, ganho de peso, biomassa, comprimento padrão e total e conversão alimentar) aos calcários calcítico e dolomítico. O pH apresentou melhor resultado no Silicato que foi semelhante ao tratamento calcítico, que não diferiu da dolomita. Alcalinidade e sílica tiveram valores maiores no silicato. A dureza e o cálcio apresentaram maiores valores nos tratamentos silicato e calcítico quando comparados ao controle e ao solo. O silicato de cálcio é uma alternativa de calagem viável e recomendada no cultivo intensivo de juvenis de tilápia do Nilo. Apresentou resultados equivalentes aos calcários calcíticos e dolomíticos, sais tradicionais para esta prática. Os calcários calcítico e dolomítico mostraram-se eficientes no processo de calagem, no sistema intensivo. A utilização do solo como material de calagem não apresentou resultados promissores. Porém, ele, assim como outros produtos, deveria ser mais bem avaliado.

PALAVRAS-CHAVE: alcalinidade; calagem; dureza; pH; qualidade da água.

INTRODUCTION

In recent years, fish consumption and production in Brazil have grown, with tilapia being the most produced and consumed fish(1). This growth enables the emergence of intensive systems, which demand greater water quality control(2). Liming, with calcitic and dolomitic limestone, are typically used to reduce variations in water quality, increasing alkalinity and hardness, buffering pH, providing a better environment(3). The soil also reacts with water, increasing the buffer capacity preventing environmental fluctuations(4). However, its buffering effect, has not been quantified in aquaculture.

Although silicate is primarily used in aquaculture as a source of silica from diatom frustules(5), silicate is considered a good alternative for liming(6,7), being more soluble than carbonates(8).

Therefore, the objective of this work was to evaluate the buffering capacity of calcium silicate and soil in intensive tilapia cultivation, compared with conventional liming products (calcite limestone and dolomitic limestone).

MATERIAL AND METHODS

The experiment to evaluate the effect of different forms of liming on Nile tilapia juveniles was carried out during 60 days in the Aquaculture Laboratory of Aquatic Ecology, DZO - UFVJM, in Diamantina (Latitude 18°14'17" South, longitude 43°36'40" West), located in the region of the Southern Espinhaço Ridge. The study was approved by the Ethics Committee on Animal Use (CEUA) of UFVJM (nº 031/2019 /CEUA-UFVJM). The experiment was composed of five treatments being: (Control) tank containing only water; Soil) water and soil; Calcitic) water and calcium carbonate ($CaCO_3$); Dolomite) water and dolomitic limestone (70% $CaCO_3$ • 30% $MgCO_3$) and Silicate) water and calcium silicate (Ca_2SiO_4). The treatments were randomly distributed in a completely randomized design, with five replicates each, being 25 aquariums. The aquarium had 10 L, aeration (30 ml min $^{-1}$), temperature (24.9 ± 1.59 °C), oxygen dissolved (5.36 ± 1.26) mg.L^{-1}, and photoperiod (12 h lightness: 12 h dark) constants. In each sampling unit 0.3 g of the salt.L^{-1} was added.

The water at the beginning of the experiment had: alkalinity, 30.20 mg L^{-1} of $CaCO_3$), pH (7.0), calcium (6.0 mg.L^{-1}), hardness (17.0 mg.L^{-1}), silica (0.02 mg.L^{-1}) and magnesium (11.0 mg.L^{-1}). The soil samples (Table 1) were air-dried, homogenized, and sieved through a 2 mm mesh (sieve no. 10). Was added 1.2 liters of soil aquarium^{-1}.

Table 1. Mean values and standard deviation of the soil composition.

Textural composition	Amount (%)
Sand	37.8 ±0.42b
Silt	46.0±0.00a
Clay	16.2±0.42c
Sieve aperture (mm)	**Retained amount (%)**
2,00	11.6 ± 0.65c
1,00	13.6 ± 0.58c
0,50	17.4 ± 0.29b
0,250	19.0 ± 0.14b
0,106	26.7 ± 0.81a
<0,106	11.4 ± 0.82c
Physico-chemical characteristics	**Mean values**
pH	6.9 ± 0.51
Redox potential (mV)	242.3 ± 17.55
Electric conductivity (mS cm^{-1})	0.03 ± 0.02
Density (g L^{-1})	1.07 ± 0.02

Means followed by distinct letters, in the same sections of the columns, differ by the Tukey's test, 0.05 probability.

The experiment started with 250 Nile tilapia juveniles (0.141 ± 0.034 mg) distributed to ten animals per tank at a density of 1 juvenile L^{-1}. To verify the fish growth, on the 60th day, they were previously anesthetized in water with a eugenol solution to measure the weight (g) in an analytical balance with an accuracy of 0.1 mg and the standard and total length with a digital caliper (Starret), with a precision of 0.02 mm. In addition, the animals were counted to calculate the survival (%) and estimated biomass (g) (weight x number of specimens in the tank). The consumption was obtained by difference between the initial and final amount at the feeding period. The weight gain (g) = (final mean weight - initial mean weight), Fulton condition factor (K), and feed conversion ratio (FCR) = (consumption weight gain^{-1}) were calculated from the data collected for consumption, initial and final weight.

The fish were fed at 8, 12 and 16 h, until apparent satiation with a commercial extruded ration with crude protein (min.) 320 g.kg^{-1}, ethereal extract (min.) 50 g.kg^{-1}, fibrous matter (max.) 70 g.kg^{-1}, mineral matter (max.) 110 g.kg^{-1}, calcium (max.) 148 30 g.kg^{-1}, phosphorus (min.) 15 g.kg^{-1} and humidity (max.) 120 g.kg^{-1}, according to the manufacturer's specifications.

Twice a week (Monday and Thursday), the aquariums were siphoned and renewed 20% of the volume, then replaced with a stock solution specific to each treatment. Every 15 days, before feeding the fish, water samples were obtained from each aquarium to measure the water quality parameters. The parameters measured were: temperature (ºC), pH, redox potential (mV), conductivity (mS.cm^{-1}), salinity (‰), turbidity (NTU) through a HORIBA U10® measuring probe; alkalinity (mg.L^{-1}), hardness (mg.L^{-1}), calcium (mg.L^{-1}), magnesium (mg.L^{-1}) determined by the titration method and the concentrations of ammonia (mg.L^{-1}), nitrite (mg.L^{-1}), nitrate (mg.L^{-1}) and silica (mg.L^{-1}) by the spectrophotometric method[9].

All data were submitted to ANOVA - one way, followed by Tukey's test 0.05 at the significance level of 0.05, using the software R.

RESULTS

The parameters of growth performance of Nile tilapia juveniles are shown in Table 2. The weight of the fish was higher in the dolomitic treatment when compared to the calcitic and did not differ from the other treatments. The total and standard length were higher in the dolomitic treatment compared to the calcitic and soil. Consumption was higher in the calcitic and soil compared to the silicate and did not diverge from the others. Feed conversion ratio, Fulton's condition factor, and biomass did not present statistical differences among the treatments. The weight gain was higher in the silicate treatment compared to the soil and did not differ from the other treatments. The biomass gain and survival were higher in the calcitic treatment regarding the silicate treatment and did not differ from the others.

Table 2. Means and standard deviation obtained from the performance of Nile tilapia submitted to different liming products.

Treatment	Weight (g)	Total length (cm)	Standard length (cm)	Consumption (g)	FCR
Control	3.6±2.07ab	5.4±0.83abc	4.3±0.74ab	3.4±6.79ab	0.78±1.13a
Calcitic	3.4±2.06b	5.3±0.83bc	4.2±0.84b	4.8±11.72a	0.78±1.15a
Dolomitic	3.9±2.16a	5.6±0.95a	4.6±0.94a	5.2±6.39ab	0.91±0.92a
Soil	3.4±1.90ab	5.2±0.74c	4.2±0.61b	7.2±8.28a	0.97±1.34a
Silicate	3.9±2.18ab	5.5±0.90ab	4.6±0.94ab	5.5±9.00 b	0.91±1.01a
Treatment	**K**	**Weight gain (g)**	**Biomass (g)**	**Biomass gain (g)**	**Survival (%)**
Control	2.1±0.71a	2.3±2.13ab	22.6±12.28a	19.3±12.65ab	70.4±22.17ab
Calcitic	2.1±0.96a	2.1±2.04ab	26.2±14.68a	23.1±14.11a	82.0±17.88a
Dolomitic	2.0±0.90a	2.4±2.17ab	21.1±10.91a	16.0±10.76ab	64.8±27.44b
Soil	2.3±0.98a	2.0±1.89b	23.6±12.09a	18.7±12.43ab	76.4±24.63a
Silicate	2.1±1.05a	2.5±2.14a	19.5±11.74a	15.2±12.96b	63.2±31.71a

Means followed by different letters in the columns differ according to Tukey's test, with a probability of 0.05. TCA = food conversion rate. K = Fulton’s condition factor.

The calcium silicate provided weight, total and standard, FCR, Fulton's condition factor, weight gain, and biomass similar to those obtained with the treatments using calcium carbonate and dolomitic. On the other hand, the consumption, biomass gain, and survival of the juveniles cultivated with silicate were similar to those of the dolomitic ones, but with higher consumption, lower biomass gain, and survival, when compared to those obtained for juveniles cultivated with calcitic. Therefore, the calcium silicate presented the same efficiency as the dolomitic limestone on the tilapia juveniles, presenting results close to, but below, three of the ten parameters measured when compared with calcitic limestone, demonstrating the efficiency of silicate as a material of liming.

The weight, consumption, FCR, Fulton's condition factor, weight gain, biomass, biomass gain, and survival of juveniles reared in the aquarium with soil were similar to juveniles cultivated using dolomitic and calcitic limestones. Compared to conventional liming products, calcitic and dolomitic limestones, the total and standard lengths were lower. Therefore, the juveniles reared in the aquarium with soil presented near yield to those reared under traditional products.

Comparing the performance of the juveniles reared in the aquariums using calcium silicate and soil, the weight, standard length, consumption, Fulton's condition factor, biomass, biomass gain, and survival were similar between the treatments. However, the total length and weight gain of the juveniles reared with silicate were higher, and the consumption was lower. Then, there verified a slight advantage in the use of the silicate when compared to the soil.

The water quality parameters in the different treatments are presented in Table 3. The pH presented higher value in the treatment silicate and calcitic, followed by dolomitic, soil and control. The parameters, potential redox, and electrical conductivity did not differ between the treatments. Turbidity was higher in the soil treatment, followed by calcitic, dolomitic, control and silicate.

The temperature was equal between treatments, with an average value of 25.0 ± 0.12 ºC. There was also no difference in oxygen concentrations between treatments, which showed average values of 5.4 ± 0.26 mg.L^{-1} and 68.7 ± 6.82%. The liming products increased pH, alkalinity, hardness, and calcium compared to the control. The ORP, conductivity, and concentrations of ammonia, nitrite, and nitrate did not show significant differences between treatments. The turbidity was higher in the soil compared to other treatments. The salinity was higher in the treatments with liming products (calcitic, dolomitic, and silicate) compared to control and soil treatments.

The alkalinity was higher in the silicate treatment, followed by the calcitic and then to the dolomitic treatment, being the lowest alkalinity observed in the control and soil treatments, which were similar to each other. The hardness and the amount of calcium in the water were higher in the silicate and calcitic treatments compared to the control and soil. The hardness of the dolomitic treatment was lower than the one observed in the silicate but similar to the calcitic and higher than the control and soil.

Table 3. Water quality means and standard deviations for Nile juvenile tilapia in intensive cultivation with different liming products.

Treatment	Temperature (ºC)	Oxigen (mg L^{-1})	Oxigen (%)	
Control	25.07 ± 1.46a	5.04 ± 0.63a	82.22 ± 39.33a	
Calcitic	24.93 ± 1.32a	5.49 ± 0.76a	65.30 ± 10.45a	
Dolomitic	24.77 ± 1.33a	5.90 ± 1.16a	72.22 ± 14.20a	
Soil	24.93 ± 1.35a	5.20 ± 0.77a	60.07 ± 12.58a	
Silicate	25.19 ± 1.49a	5.20 ± 0.46a	63.64 ± 5.97a	
Treatment	pH	ORP (mV)	Conductivity (mS cm^{-1})	Turbidity (NTU)
Control	7.4±0.55d	148.2±52.12a	0.4±0.06a	118.7±113.67b
Calcitic	7.9±0.33ab	166.1±177.92a	0.5±0.08a	194.6±136.62b
Dolomitic	7.8±0.45bc	132.0±55.24a	0.4±0.07a	115.3±126.15b
Soil	7.5±0.48cd	135.1±58.46a	0.4±0.04a	521.2±296.43a
Silicate	8.0±0.44a	124.2±39.45a	0.7±0.09a	93.6±67.01b
Treatment	Salinity (‰)	Ammonia (mg L^{-1})	Nitrite (mg L^{-1})	Nitrate (mg L^{-1})
Control	0.00±0.00b	0.5±0.71a	0.2±0.30a	0.2±0.34a
Calcitic	0.01±0.00a	0.2±046a	0.4±0.50a	0.4±0.60a
Dolomitic	0.01±0.00a	0.3±0.55a	0.4±0.34a	0.2±0.37a
Soil	0.00±0.00b	0.5±0.49a	0.3±0.43a	0.0±0.28a
Silicate	0.01±0.00a	0.6±0.87a	0.3±0.45a	0.1±0.31a
Treatment	Alkalinity (mg L^{-1})	Hardness (mg L^{-1})	Calcium (mg L^{-1})	Silica (mg L^{-1})
Control	32.8±2.51d	49.0±16.87c	36.0±16.63c	0.02±0.01b
Calcitic	41.9±2.97b	93.7±26.06ab	77.3±27.78ab	0.01±0.00b
Dolomitic	37.0±3.15c	73.4±28.47b	58.7±24.34b	0.01±0.00b
Soil	29.5±2.52d	36.0±12.63c	25.6±6.02c	0.01±0.00b
Silicate	56.2±8.80a	95.7±40.31a	79.4±30.68a	0.04±0.00a

Means followed by different letters in the columns differ according to Tukey's test, with a probability of 0.05. ORP = redox potential

DISCUSSION

PERFORMANCE OF JUVENILES

All measured parameters of yield, weight, total and standard length, consumption, feed conversion, Fulton condition factor, weight gain, biomass, biomass gain and survival of tilapia juveniles cultivated with water added with calcium silicate were similar to those cultivated on dolomitic and calcitic limestone.

Considering that dolomitic and calcitic are the limestone standards in Aquaculture[10,11,12], with juveniles in silicate presenting similar yield to dolomite and calcitic, calcium silicate should be considered as an alternative alkalizer (liming product). Juveniles grown in silicate developed better than those grown in soil. The silicate juveniles presented higher weight gain, total length, and lower consumption than in the aquarium with soil at the bottom. However, tilapia juveniles cultivated in the soil showed the same results as those yield with limestone and were smaller only in total length and pattern observed in dolomitic. This example demonstrates that the soil was able to interact, altering the water quality in nursery tanks, as suggested by[13], but in a moderate way.

Despite the similarity in survival rates between calcite (82.0%) and silicate (63.2%), there is a tendency for calcite to have more individuals per aquarium, which results in greater density and biomass gain. This survival, biomass, and density relationship have already been observed in other works[14,15] that verified loss in the final weight, weight gain, specific growth rate, length, Fulton's condition factor, and an increase in the feed conversion rate, trends not observed in this experiment.

WATER QUALITY - GENERAL

In this experiment, it was possible to observe that maintaining good water quality associated with other appropriate management results in adequate growth. However, even within this range considered acceptable, changes in water quality result in different levels of growth. A better crop response is achieved when values are closer to ideal, there are fewer fluctuations, or there is a longer period of adequate conditions.

The water quality parameters: temperature, dissolved oxygen concentration, water pH degree, ammonia (NH_3), nitrite (NO_2), and nitrate (NO_3) concentration can significantly alter body weight, composition, behavior, feed intake, feed conversion ratio, feeding efficiency, health, reproduction, and survival rates of *Oreochromis niloticus*[16].

The water quality parameters were within the range considered suitable for tilapia cultivation, perhaps except for turbidity, except in the soil treatment, due to suspended clay[16-19], which may explain the lower length and weight gain of fish in the soil treatment than in the silicate. Although tilapia usually grow in environments with suspended clay, they should be avoided as they can overload the fish's physiology, harm the gills, and cause disease[20]. The temperature and oxygen were equal between treatments and adequate for the species, so it did not affect the differences observed between treatments.

pH, ALKALINITY AND HARDNESS

The pH, alkalinity, and hardness increased by liming. The soil presented alkalinity and hardness equal to the treatment with water alone (control) and lower than the others, and its pH was the same to that of only water and dolomite. The liming to increase pH, alkalinity, and hardness, improving the stability and productivity of cultivation systems, is a common practice[12,13,21,22]. The water with agricultural limestone has roughly doubled conductivity and concentrations of total alkalinity, total hardness, and calcium hardness in the discharge water[23].

Despite the lower pH in the control treatment, the values in this experiment were close (7.4 to 8.0) and suitable for fish cultivation[13], within the range indicated for aquaculture in resolution BRAZIL - CONAMA 357/2005 class II[24], and for the species[25], which justify the similarity observed in most performance parameters.

By increasing alkalinity, a buffer effect occurs, preventing other parameters, such as pH, from varying sharply, improving the conditions for animal cultivation[13,26], which will allow water with adequate quality for longer than the one that did not receive liming[12].

The alkalinity of this experiment was favorable for tilapia culture despite the differences observed between the treatments. The alkalinity was above the indicated value of 20 mg L^{-1} and within the range of freshwater fish culture[27], specifically for tilapia cultivation described by[25] (22.72 to 27.26 mg L^{-1}) and[28] (39.6 to 94.4 mg L^{-1}).

The hardness values observed in this experiment, 30 and 95 mg L^{-1}, were over minimum concentration and within the wide range considered appropriate for the species despite there are differences between treatments. The waters that received liming products (liming materials), composed of calcium or calcium and magnesium, had a higher hardness level.

The hardness refers to the number of ions dissolved in the water, mainly calcium and magnesium. Lime is an important source of alkalinity and hardness, as well as the calcium silicate and feldspars, such as olivine, orthoclase, and several others[3], thus explaining the higher values of hardness in the treatments with the applicaion of liming products.

Generally, water has low hardness and salt content, mainly calcium and magnesiu[29], which did not occur in this experiment, where the lowest hardness value was above the minimum hardness value indicated for fish farming, which is 20 mg L^{-1}[26,30]. Although hardness values are above the recommended minimum, other studies, where hardness ranged from 39.6 to 1000 mg.L^{-1} $CaCO_3$, show that the best hardness level depends on the stage of development and the situation to which the tilapia is subjected[28,31-35]. The high hardness values (73.4 - 95.7 mg.L^{-1}) were associated with the best results in this experiment.

ELECTRICAL CONDUCTIVITY AND TURBIDITY

The electrical conductivity of this experiment ranged between 0.4 and 0.8 mS cm^{-1}, slightly above the indicated range (0.12 mS.cm^{-1} and 0.5 mS.cm^{-1}) for freshwater fish culture[36]. High electrical conductivity values are related to fish tank management dynamics, where a large amount of organic matter is constantly added by diet(37). Conductivity values increase with the addition of fish feed, mainly in the intensive, recirculating system, in which the ammonium level is maintained at the biological limit to reduce the cost of pumping without affecting animals(38).

Although the high conductivity values are related by feed addition, the higher value observed in the calcitic and silicate treatments compared to the control is given by adding salts. Similarly, in the fish pond of Alabama, when is added limestone in the water, the conductivity doubles in the discharge water(23).

High turbidity was detrimental to fish growth, as observed in this experiment. As for turbidity, the Resolution BRAZIL - CONAMA 357/2005 class II recommends values of up to 100 NTU(24), and during the experiment, it reached up to 520 NTU. The turbidity of the soil treatment was higher than the others, which can be explained due to the suspended sediment. The turbidity is related to the presence of organic matter, phytoplankton and zooplankton communities, and inorganic debris, such as sands and clays present in the soil(25), which is harmful to fish(20,32).

The turbidity value in calcitic (194.6 NTU) was approximately twice that of control (118.7 NTU), dolomitic (115.3 NTU), and silicate (93.6 NTU), despite being statistically similar. This difference in turbidity may help explain why fish subjected to calcite had lower weight and length than those cultured in dolomite. A similar response was observed for tilapia subjected to different alkalinizes, where the turbidity of the limestone was higher and responsible for the lower tilapia growth(32).

CALCIUM AND SILICA

During the period and treatments of this experiment, calcium was not a limiting factor, even on the first day of the control treatment. The water is considered low in calcium when the concentration is below 2.5 mg L-1 $CaCO_3$(39). This calcium concentration in water is within the range considered suitable for a fish diversity species(40) without compromising growth and survival. In addition, the amount of calcium dissolved in water did rise over the days, which can be explained by the continuous inflow of calcium through the fish's diet, which increases the hardness[41]. The calcium in the water compensates for the lack of calcium in the feed, which is essential for many processes, such as bone building, blood coagulation, and other cellular functions, besides avoiding an ionic loss to the water[41].

Aquatic animals have unique physiological mechanisms to absorb and retain minerals, essentiality microminerals (calcium, phosphorus, magnesium, sodium, potassium, and chloride), and certain trace elements (cobalt, copper, iodine, iron, manganese, selenium, and zinc) from their diets and water[42]. Several factors or their combinations, such as environmental factors (water mineral concentration) and diet and biological factors, may affect the minimal dietary levels of mineral and trace elements in fish[40].

Although calcium can be absorbed directly from the water, compensating for some deficiency in the feed, the feed used was specific for juveniles, and the concentrations of calcium and magnesium were apparently within the range suitable for cultivation. Therefore, in this experiment, the concentrations of calcium and magnesium mainly interfered indirectly, increasing hardness, alkalinity, and pH, buffering the medium, and making it more stable for cultivation.

REDOX POTENTIAL AND SALINITY

The averages recorded for redox potential presented values between 120.0-220.0 mV, close to the average value found in the cultivation of Nile tilapia, 155.3 mV, in a biofloc system, which were considered suitable for the cultivation of the species, and typical of an oxygen-rich environment[43], as was also verified in this experiment.

Water salinity varied between 0 and 0.01 ‰, with 0.01 ‰ only observed in treatments where liming was applied. Therefore, these waters are classified as freshwater[44], and the low salinity observed has little influence on other water characteristics, such as oxygen and ammonia levels[11].

AMMONIA, NITRITE AND NITRATE

Considering the temperature, pH, and oxygen observed in this experiment, associated with total ammonia concentrations (0.2 to 0.6), ionized (NH_4^-), and non-ionized ammonia (NH_3), this parameter was not a concern for the species. The worrying level of non-ionized ammonia is 0.2 mg L^{-1}[10, 45, 46]. Toxic levels of non-ionized ammonia short exposures are generally reported to be between 0.6 and 2mg.L^{-1}[47]. The proportion of NH_3 increases when pH and temperature increase[48]. When the pH is close to 7.0, only 0.7% of the total ammonia are in the toxic form (NH_3), so it is not a concern for fish health, but when the pH is 9.0 or higher, 40% or more of the total ammonia is found in toxic form, which can be harmful to growth or even kill[46]. Likewise[25] did not report that ammonia levels negatively affected tilapia cultivation when observing concentrations of total ammonia (0.29 to 0.42 mg.L^{-1}), such as those observed in this experiment, at a higher temperature (27.0 at 31.8 ºC), but slightly lower pH (5.6 to 6.9).

Nitrite concentrations, 0.2 – 0.4 mg.L^{-1}, in this experiment, were close to the limit suitable for fish farming[45] and above the limit for aquaculture water in Brazilian legislation, CONAMA Resolution 357/2005[24]. On the other hand, nitrate concentrations (0.1 - 0.4 mg.L^{-1}) were well below the concentration of concern, 25 mg.L^{-1}[45], and compared to nitrite and ammonia concentration suggests that nitrification was inefficient due to the lack of substrate for the bacteria to attach[11,46]. Therefore, nitrogen compounds did not interfere with the variations among treatments during cultivation and were suitable.

CONCLUSION

Calcium silicate is a viable and recommended alternative liming in the intensive cultivation of juvenile Nile tilapia. He presented results equivalent to calcitic and dolomitic limestones, traditional salts for this practice. Calcitic and dolomitic limestones proved to be efficient in the liming process, in the intensive system.

The use of soil as a liming material did not show promising results. However, it, like other products, should be more evaluated.

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Williane Ferreira Menezes, Master's student, Marcelo Mattos Pedreira, advisor, and Marianne Schoorer, José Cláudio Epaminondas dos Santos, Emilene Rodrigues Souza, Rodrigo Sá Fortes Pedreira, and Matheus Philip Santos Amorim and Afonso Pelli were collaborating researcher.

REFERENCES

(1) Peixe, BR. 2022. Anuário peixe BR da piscicultura. São Paulo, Associação Brasileira de Piscicultura.

(2) Kubitza, F. 2018. A onda da criação de peixes em caixas d'água. Panorama da Aquicultura, v.167: 15-25.

(3) Boyd, CE; Tucker, CS; Somridhivej, B. 2016. Alkalinity and hardness: critical but elusive concepts in aquaculture. Journal of the World Aquaculture Society, 47(1): 6–41. 10.1111/jwas.12241.

(4) Boyd, CE; Queiroz, JF. 2014. The role and management of bottom soils in aquaculture ponds. INFOFISH International 2: 22-28 Available in: <http://www.infofish.org.br> Access at: 3 de may 2022.

(5) Boyd, CE. 2014. Silicon, diatoms in aquaculture. Global Aquaculture Advocate, 18(3): 38-39.

(6) Smith, CJ; Peoples, MB; Keerthisinghe, G; James, TR; Garden, DL; Tuomi, SS. 1994. Effect of surface applications of lime, gypsum and phosphogypsum on the alleviating of surface and subsurface acidity in a soil under pasture. Soil Research, 32(5): 995–1008. https://doi.org/10.1071/SR9940995.

(7) Reis, JJD; dos Alovisi, AMT; Ferreira, JAA; Alovisi, AA; Gomes, CF. 2013. Atributos químicos do solo e produção da cana-de-açúcar em resposta ao silicato de cálcio. Rev. de Ciências Agrárias, 36(1): 3-9. https://doi.org/10.19084/rca.16274.

(8) Castro, GSA; Crusciol, CAC. 2013. Effects of superficial liming and silicate application on soil fertility and crop yield under rotation. Geoderma, 195-196: 234–242. https://doi:10.1016/j.geoderma.2012.12.006.

(9) APHA - American Public Health Association. 2012. Standard methods for the examination of water and wastewater. 22nd. Rice, E.W.; Baird, R.B.; Eaton, A.D.; Clesceri, L.S. Washington, D.C.: American Public Health Association, American Water Works Association, Water Environment Federation. 1496p.

(10) Boyd, CE; Tucker, CS. Pond aquaculture water quality management. Springer Science & Business Media, 2012.

(11) Boyd, CE. Water quality: an introduction. Springer Nature. 2019.

(12) Pedreira, MM. Calagem na manutenção da qualidade da água na aquicultura. p.154-171. In: Membrive, C. M. B.; Bernardes, E. M.; Rosas, F. S.; Fonseca, R. (org.). IMAST 2023: IV International Meeting of Agrarian Science and Technology**.** Dracena: FCAT; Marília: Ladri. 2023.

(13) Boyd, CE; Tucker, CS. 2019. Water quality. Aquaculture: Farming Aquatic Animals and Plants; John Wiley & Sons: Chichester, West Sussex, UK, 63-92.

(14) Moniruzzaman, M; Uddin, KB; Basak, S; Mahmud, Y; Zaher, M; Bai, SC. 2015. Effects of stocking density on growth, body composition, yield and economic returns of monosex tilapia (*Oreochromis niloticus* L.) under cage culture system in Kaptai Lake of Bangladesh. Aquaculture Research & Development, 6(8): 1. http://dx.doi.org/10.4172/2155-9546.1000357.

(15) Wu, F; Wen, H; Tian, J; Jiang, M; Liu, W; Yang, C; Yu, L; Lu, X. 2018. Effect of stocking density on growth performance, serum biochemical parameters, and muscle texture properties of genetically improved farm tilapia, *Oreochromis niloticus*. Aquaculture, 26(5): 1247–1259. https://doi.org/10.1007/s10499-018-0281-z.

(16) Abd El-Hack, ME; El-Saadony, MT; Nader, MM; Salem, HM; El-Tahan, AM; Soiman, SM; Khafaga, AF. 2022. Effect of environmental factors on growth performance of Nile tilapia (*Oreochromis niloticus*). Int J Biometeorol, 66, 2183–2194. https://doi.org/10.1007/s00484-022-02347-6

(17) Makori, AJ; Abuom, PO; Kapiyo, R; Anyona, DN; Dida, GO. 2017. Effects of water physico-chemical parameters on tilapia (*Oreochromis niloticus*) growth in earthen ponds in Teso North Sub-County, Busia County. Fisheries and Aquatic Sciences, 20(1), 30–. doi:10.1186/s41240-017-0075-7.

(18) Brito, JMD; Ferreira, AHC; Santana Júnior, HÁ; Oliveira, APA, Santos, CHL; Oliveira, LTS. 2019. Desempenho zootécnico de juvenis de tilápias do Nilo (*Oreochromis niloticus*) alimentados com cepas probióticas e submetidos a desafio sanitário. Ciência Animal Brasileira, 20, e-37348. https://doi.org/10.1590/1809-6891v20e-37348.

(19) Shamsuddin, M, Hossain, MB, Rahman, M; Kawla, MS, Tazim, MF, Albeshr, MF; Arai, T. 2022. Effects of stocking larger-sized fish on water quality, growth performance, and the economic yield of Nile tilapia (*Oreochromis niloticus* L.) in floating cages. Agriculture, 12(7), 942. https://doi.org/10.3390/agriculture12070942.

(20) Flik, G; Verbost, PM; Bonga, SEW. 1995. Calcium transport processes in fishes. Fish Physiology, 14: 317-342. https://doi.org/10.1016/S1546-5098(08)60251-4.

(21) Hickling, CF. Fish culture. London: Faber and Faber. 295 p. IBGE - Instituto Brasileiro de Geografia e Estatística. 2016. Produção da pecuária municipal. IBGE, 44: 1-51. 1962.

(22) Arce, RG; Boyd, CE. 1975. Effects of agricultural 495 limestone on water chemistry, phytoplankton productivity, and fish production in soft water ponds. Transactions of the American Fisheries Society, 104: 308-312. https://doi.org/10.1577/1548-8659(1975)104<308:EOALOW>2.0.CO;2

(23) Somridhivej, B; Boyd, CE. 2016. Effects of liming on quality of water discharged from the supply reservoir at a fisheries research station. North American Journal of Aquaculture, 78(4), 356-361. https://doi.org/10.1080/15222055.2016.1194925.

(24) BRASIL, CONAMA. 2005. Resolução. 357, de 17 de março de 2005. Conselho Nacional do Meio Ambiente-CONAMA, v. 357.

(25) Mercante, CTJ; Martins, YK.; Carmo, CF; Osti, JS; Mainardes-Pinto, CSR; Tucci, A. 2007. Qualidade da água em viveiro de tilápia do Nilo (*Oreochromis niloticus*): caracterização diurna de variáveis físicas, químicas e biológicas. Bioikos, 21(2): 79-88.

(26) Boyd, CE; Tucker, CS. Pond aquaculture water quality management. Boston: Kluwer Academic Publishers. 1998. 700p. https://doi.org/10.1007/978-1-4615-5407-3.

(27) Andrade, LS; Andrade, RLB; Becker, AG; Rossato, LV; Rocha, JF; Baldisserotto, B. 2007. Interaction of water alkalinity and stocking density on survival and growth of silver catfish, *Rhamdia quelen*, juveniles. Journal of the World Aquaculture Society, 38(3): 454-458. https://doi.org/10.1111/j.1749-7345.2007.00118.x.

(28) Bart, AN; Prasad, B; Thakur, DP. 2013. Effects of incubation water hardness and salinity on egg hatch and fry survival of Nile tilapia *Oreochromis niloticus* (Linnaeus). Aquaculture Research, 44(7): 1085-1092. https://doi.org/10.1111/j.1365-2109.2012.03113.x.

(29) Baldisserotto, B. 2003. Osmoregulatory adaptations of freshwater teleosts. In: Val, AL; Kapoor, BG. Fish Adaptations. Enfield: Science Publishers. p. 179-201.

(30) Boyd, CE. Water quality in warmwater fishponds. Auburn: Auburn University, 1979.

(31) Dogan, Z; Eroglu, A; Kanak, EG; Atli, G; Canli, M. 2014. Response of Antioxidant System of Tilapia (*Oreochromis niloticus*) Following Exposure to Chromium and Copper in Differing Hardness. Bull Environ Contam Toxicol, **92**, 680–686. https://doi.org/10.1007/s00128-014-1245-2.

(32) Martins, GB; Tarouco, F; Rosa, CE; Robaldo, RB. 2017. The utilization of sodium bicarbonate, calcium carbonate or hydroxide in biofloc system: water quality, growth performance and oxidative stress of Nile tilapia (*Oreochromis niloticus*). Aquaculture, 468, 10-17. https://doi.org/10.1016/j.aquaculture.2016.09.046.

(33) Martins, GB; da Rosa, CE; Tarouco, FDM; Robaldo, RB. 2019. Growth, water quality and oxidative stress of Nile tilapia *Oreochromis niloticus* (L.) in biofloc technology system at different pH. Aquaculture Research, 50(4), 1030-1039.

(34) Özçelik S, Canli M. 2023. Combined effects of metals (Cr6+, Hg2+, Ni2+, Zn2+) and calcium on the serum biochemistry and food quality of the Nile fish (*Oreochromis niloticus*). Journal of Food Composition and Analysis. 115 (1): 104968. https://doi.org/10.1016/j.jfca.2022.104968.

(35) Matos, CR. Níveis de dureza total da água, pela adição de cloreto de cálcio, no cultivo de juvenis de tilápias do Nilo. Dissertação Mestrado, Zootecnia -UFVJM – MG, 2020.

(36) Tapader, MMA; Hasan, MM; Sarker, BS; Rana, MEU; Bhowmik, S. 2017. Comparison of soil nutrients, pH and electrical conductivity among fish ponds of different ages in Noakhali, Bangladesh. Korean Journal of Agricultural Science, 44(1): 16-22. https://doi.org/10.7744/kjoas.20170002.

(37) Akkoyunlu, A; Akiner, ME. 2012. Pollution evaluation in streams using water quality indices: A case study from Turkey's Sapanca Lake Basin. Ecological Indicators, 18: 501-511. https://doi.org/10.1016/j.ecolind.2011.12.018.

(38) Gharib, AA, Abdel-Hamid, EAA, Mousa, MAA et al. 2022. Improving water quality, growth performance, and modulating some stress physiological biomarkers in *Cyprinus carpio* using raw date nuclei as a zinc adsorbent agent. Appl Water Sci 12, 159. https://doi.org/10.1007/s13201-022-01682-8

(39) Perry, SF; Wood, CM. 1985. Kinetics of branchial calcium uptake in the rainbow trout: effects of acclimation to various external calcium levels. Journal of Experimental Biology, 16(1): 411-433.

(40) Antony Jesu Prabhu, P; Schrama, Johan W; Kaushik, Sadasivam J. 2016. Mineral requirements of fish: a systematic review. Reviews in Aquaculture, 216(8), 172-219. doi:10.1111/raq.12090.

(41) Poleo, G; Aranbarrio, JV; Mendoza, L; Romero, O. 2011. Cultivo de cachama blanca en altas densidades y en dos sistemas cerrados. Pesquisa Agropecuária Brasileira, 46(4): 29-437. https://doi.org/10.1590/S0100-204X2011000400013.

(42) Lall, SP; Kaushik, SJ. 2021. Nutrition and metabolism of minerals in fish. Animals, *11*(09), 2711. https://doi.org/10.3390/ani11092711.

(43) Magondu, EW; Verdegem, MCJ; Nyakeya, K; Mokaya, M. 2015. Production of aerobic, anaerobic and anoxic bioflocs from tilapia sludge. International Journal of Fisheries and Aquatic Studies, 2 (5), 347-352.

(44) Boyd, CE.; McNevin, AA. 2015. Aquaculture, resource use, and the environment. Hoboken: John Wiley & Sons, Inc.. 368p. doi:10.1002/9781118857915.

(45) Kubitza, F. Qualidade da água no SARs – monitoramento e correção. Panorama da Aquicultura, v. 31, p. 14-23. 2022a.

(46) Kubitza, F. Resíduos sólidos e nitrogenados – origem, quantificação e manejo. Panorama da Aquicultura, v. 31, p. 14-23. 2022b.

(47) Liew, HJ; Sinha, AK; Nawata, CM; Blust, R; Wood, CM; Boeck, G. 2013. Differential responses in ammonia excretion, sodium fluxes and gill permeability explain different sensitivities to acute high environmental ammonia in three freshwater teleosts. Aquatic Toxicology, 126: 63–76. https://doi.org/10.1016/j.aquatox.2012.10.012.

(48) Trussell, RP, 1972. The percent un-ionized ammonia in aqueous ammonia solutions at different pH levels and temperatures. Journal of the Fisheries Research Board of Canada, 29(10): 1505–1507. https://doi.org/10.1139/f72-236.