# CALCIUM AND MAGNESIUM SILICATE AND SOIL AS ENVIRONMENTAL STABILIZERS IN THE CULTIVATION OF NILE TILAPIA LARVAE IN THE RECIRCULATION SYSTEM

# *SILICATO DE CÁLCIO E MAGNÉSIO E SOLO COMO ESTABILIZADORES AMBIENTAIS NO CULTIVO DE LARVAS DE TILÁPIA-DO-NILO EM SISTEMA DE RECIRCULAÇÃO*

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## ABSTRACT

With the intensification of production systems and the need to reduce water use, there is a greater likelihood of sudden changes in water quality, leading to fish mortality. Therefore, it is necessary to develop techniques that increase environmental homeostasis. This experiment evaluated the influence of calcium-magnesium silicate and soil compared to calcium carbonate and calcium-magnesium carbonate, traditional alkalizers, as environmental stabilizers in cultivating Nile tilapia larvae in a recirculating system. The experiment was composed of five treatments: Control) aquarium containing only water; Soil) water and soil; Calcitic) water and calcium carbonate ($CaCO_3$); Dolomite) water and dolomitic limestone ($CaCO_3$ $MgCO_3$) and Silicate) water and calcium-magnesium silicate ($CaSiO_3$ $MgSiO_3$). After 30 days, the performance parameters, weight, standard length, total length, Fulton condition factor, weight gain, biomass, biomass gain, and survival, did not differ among treatments. Among the water quality parameters, temperature (30 °C) and oxygen (5 to 6 mg $L^{-1}$) were maintained with heaters and aeration throughout the period. The parameters conductivity, pH, redox potential, salinity, turbidity, ammonia, nitrite, nitrate, alkalinity, hardness, calcium, magnesium, and silica were measured. The pH was higher in the silicate and calcitic treatments than in the control. The dolomitic treatment was higher for the redox potential than in the soil. The electrical conductivity was higher in the soil treatment than in the control. The turbidity in the soil was higher than in the other treatments. Salinity was higher in treatments that received liming products but with low values. Ammonia concentration was higher in the control treatment than in the silicate. Nitrite and nitrate concentrations did not differ between treatments. Alkalinity was higher in the silicate treatment. Hardness was higher in the calcitic, dolomitic, and silicate treatments than in control and soil. Calcium dissolved in water was higher in the calcitic and silicate treatments than in the control and soil. Silica dissolved in water was higher in silicate. Calcium-magnesium silicate is a viable and recommended alternative for liming, as it presents results equivalent to calcitic and dolomitic limestone, traditional salts for this practice, which confirms its importance in maintaining water quality and fish performance. Although the soil has a buffering capacity in the water, it is less effective than other products and deserves further study.

**KEYWORDS**: Alkalinity, Hardness, Liming, pH, Water homeostasis.

## RESUMO

Com a intensificação dos sistemas de produção e a necessidade de redução do uso de água, há maior probabilidade de mudanças bruscas na qualidade da água, levando à mortalidade de peixes. Portanto, é necessário desenvolver técnicas que aumentem a homeostase ambiental. Este experimento avaliou a influência do silicato de cálcio-magnésio e do solo em comparação ao carbonato de cálcio e ao carbonato de cálcio-magnésio, alcalinizantes tradicionais, como estabilizadores ambientais no cultivo de larvas de tilápia do Nilo em sistema de recirculação. O experimento foi composto por cinco tratamentos: Controle) aquário contendo apenas água; Solo) água e solo; Calcítico) água e carbonato de cálcio ($CaCO_3$); Dolomítico) água e calcário dolomítico ($CaCO_3$ $MgCO_3$) e Silicato) água e silicato de cálcio-magnésio ($CaSiO_3$ $MgSiO_3$). Após 30 dias, os parâmetros de desempenho, peso, comprimento padrão, comprimento total, fator de condição de Fulton, ganho de peso, biomassa, ganho de biomassa e sobrevivência, não diferiram entre os tratamentos. Entre os parâmetros de qualidade da água, a temperatura (30 °C) e oxigênio (5 a 6 mg $L^{-1}$) foram mantidos com aquecedores e aeração durante todo o período. Os parâmetros condutividade, pH, potencial redox, salinidade, turbidez, amônia, nitrito, nitrato, alcalinidade, dureza, cálcio, magnésio e sílica foram medidos. O pH foi maior nos tratamentos silicato e calcítico do que no controle. O tratamento dolomítico foi maior para o potencial redox do que no solo. A condutividade elétrica foi maior no tratamento solo do que no controle. A turbidez no solo foi maior do que nos outros tratamentos. A salinidade foi maior nos tratamentos que receberam produtos de calagem, mas com valores baixos. A concentração de amônia foi maior no tratamento controle do que no silicato. As concentrações de nitrito e nitrato não diferiram entre os tratamentos. A alcalinidade foi maior no tratamento silicato. A dureza foi maior nos tratamentos calcítico, dolomítico e silicato do que no controle e solo. O cálcio dissolvido em água foi maior nos tratamentos calcítico e silicato do que no controle e solo. A sílica dissolvida em água foi maior no silicato. O silicato de cálcio-magnésio é uma alternativa viável e recomendada para calagem, pois apresenta resultados equivalentes aos calcários calcítico e dolomítico, sais tradicionais para essa prática, o que confirma sua importância na manutenção da qualidade da água e no desempenho dos peixes. Embora o solo tenha capacidade tampão na água, ele é menos eficaz que outros produtos e merece estudos mais aprofundados.

**PALAVRAS-CHAVE**: Alcalinidade; Calagem; Dureza; Homeostase da água, pH.

## INTRODUCTION

The annual production growth recorded since 2000 is due to the intensification process, where production management, food, and biosecurity have improved. In this sense, aquaculture needs to pay greater attention to the health of the production environment, where keeping water quality is a challenge[1]. Meeting the global demand for aquatic products and, at the same time, maintaining sustainability is a critical challenge where it is necessary to combine technological solutions, innovations, and best management practices, increasing efficiency in an ecosystem approach to aquaculture resources[2].

Elevated alkalinity levels have been used in aquaculture to prevent rapid pH fluctuations, improve water quality, maintain the health and well-being of fish, and increase production in intensive systems characterized by numerous physical, chemical, and biological interactions[3].

Although alkalinity, as well as total hardness, another environmental stability parameter closely related to alkalinity, are familiar variables in aquatic animal production, where both scientists and aquaculturists have some knowledge of methods for adjusting their concentrations, their chemical relationships and biological effects are more complex than generally realized or described in the literature[4].

Alkalinity is necessary for pH stability, which has a direct impact on the toxicity of ammonia, $CO_2$, and other metabolic compounds, as well as providing inorganic carbon for nitrifying bacteria, which are essential for the functioning of the culture, as well as on the efficiency of critical processes such as nitrification and $CO_2$ removal (Jafari et al., 2024)[3]. Interactions are diverse, with different responses requiring detailed assessments[3-5].

Calcitic limestone, composed of calcium carbonate, and dolomitic limestone, calcium carbonate with magnesium, are the alkalizing agent generally used because they are easily accessible and cheap[6]. Other products that increase alkalinity have been used, such as calcium silicate, which is occasionally used[4], sodium carbonate, which is highly soluble and reacts quickly been is safe for fish and humans as well as sodium bicarbonate and calcium hydroxide, this which, despite being dangerous, is commonly used because it is cheaper and more readily available than sodium carbonate[7]. However, with intensification, production in closed systems requires adjustments, such as using new products or the same alkalinizing products with different quality and concentrations than those usually used[5].

In the aquaculture intensive, the alkalizing agents also have been selected based on results associated with ease of obtaining and price, and this is the case with sodium silicate, sodium bicarbonate, and calcium carbonate powder used in the recirculation system[8], and sodium bicarbonate, calcium carbonate or calcium hydroxide in a biofloc system[9].

Sodium bicarbonate ($NaHCO_3$) has been used in intensive systems due to its efficiency in rapidly increasing alkalinity and pH, being safe for both animals and fish farmers, in addition to being affordable[8,9]. Calcium hydroxide ($Ca(OH)_2$) is also very efficient in increasing pH and alkalinity, producing good results in intensive production systems. However, because it is highly reactive, it can cause fish mortality and should be used more sparingly[9]. Calcium carbonate powder increases pH and alkalinity for a prolonged period, taking longer to dissolve[8], and generates greater turbidity, which can compromise fish growth[9]. Sodium silicate dissolves quickly, promptly altering the pH and presenting results closed with sodium bicarbonate and calcium carbonate[8].

Although calcium silicate raises alkalinity and pH to a level slightly below that of agricultural limestone and has a water solubility similar to that of calcium carbonate[10], there is rarely a study evaluating its efficiency in an intensive fish culture system, even in a conventional system, which generates a demand for studies with this product.

The sediment at the bottom of the tank is an essential part of the farming ecosystem, exchanging nutrients at the soil-water interface, with feldspars composed of calcium silicate raises the pH[4] while the aluminum acidifying[10] influencing water quality and, consequently, affecting animal growth and welfare[11,12]. Despite the importance of sediment in this ecosystem, sediment has yet to be studied as a possible factor in improving conditions in intensive systems of tilapia larva culture.

For the reasons described above, this work aimed to evaluate the influence of calcium-magnesium silicate and soil compared to traditional limning calcium carbonate and calcium and magnesium carbonate on tilapia larva culture.

## MATERIAL AND METHODS

The experiment to evaluate the effect of different forms of liming on Nile tilapia larvae was carried out during 30 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) protocolo 001\2017. The experiment was composed of five treatments being: Control) aquarium 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-magnesium silicate ($CaSiO_3$ $MgSiO_3$). The treatments were randomly distributed in a completely randomized design, with five replicates each, being 25 aquariums. The aquarium had 10 L, aeration (40 ml $min^{-1}$, >4.7 mg $L^{-1}$ $O_2$), temperature (30 °C), 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 began with 375 specimens of Nile tilapia larvae weighing 0.02 ± 0.00 g, measuring the standard length of 1.12 ± 0.08 cm and total length of 0.93 ± 0.08 cm, and subsequently distributed 15 animals per aquarium at a density of 1.5 $larvaL^{-1}$. The animals were fed commercial powdered feed, with crude protein (min.) 550 g $kg^{-1}$, ether extract (min.) 80 g $kg^{-1}$, fibrous matter (max.) 30 g $kg^{-1}$, mineral matter (max.) 160 g $kg^{-1}$, calcium (max.) 30 g $kg^{-1}$, phosphorus (min.) 14 g $kg^{-1}$ and moisture (max.) 100 g $kg^{-1}$, according to the manufacturer's specifications, offering until apparent satiation, in three meals: 8, 12 and 16 h.

Twice a week (Monday and Thursday), the aquariums were cleaned by siphoning, and 20% of the volume was renewed and replaced with a specific stock solution for each treatment. Before feeding the fish, every fifteen days (1, 15, and 30 days), water samples were obtained from each aquarium to control their parameters. The parameters measured were: temperature (°C), pH, redox potential (mV), conductivity ($mScm^{-1}$), salinity (‰), turbidity (NTU) using a HORIBA U10® measuring probe; alkalinity (mg $L^{-1}$), hardness (mg $L^{-1}$), calcium (mg $L^{-1}$), magnesium (mg $L^{-1}$)

using the titrimetric method; and the concentrations of ammonia (mg $L^{-1}$), nitrite (mg $L^{-1}$), nitrate (mg $L^{-1}$) and silica (mg $L^{-1}$) using the spectrophotometric method, as indicated by APHA[13].

At the end of the experiment, measurements of total and standard length (cm) were taken with a digital caliper (Starret) with an accuracy of 0.02 mm and weight (g) with an analytical balance with an accuracy of 0.01 g when the number of individuals was also counted to calculate survival (%). From these records, weight gain (g) = (final weight - initial weight), biomass (g) (average weight x number of specimens per aquarium), biomass gain (g) = (final biomass - initial biomass), and Fulton's condition factor (K) [(= 100 × (total length weight$^{-3}$), were calculated.

The data were subjected to normality tests (Shapiro-Wilk) and homoscedasticity. Survival data were transformed into arcsine for statistical analysis but were shown in percentages. The data were subjected to one-way ANOVA and Tukey's test at a significance level 0.05. For calculations, the R software was used.

## RESULTS

The parameters of growth and survival of Nile tilapia larvae are presented in Table 2. Total length, standard length, weight, weight gain, biomass, biomass gain, Fulton condition factor, and survival did not show differences between treatments.

The water quality parameters in the different treatments in the Nile tilapia larvae culture are shown in Tables 3, 4, and 5. The data on dissolved oxygen in the water, nitrite, nitrate, and magnesium did not differ significantly according to the products tested ($p>0.05$). The parameters pH, redox potential, electrical conductivity, turbidity, salinity, ammonia, alkalinity, hardness, calcium, and silica showed significant differences ($p<0.05$) between the liming products and the soil, as well as the absence of them.

Table 2. Mean values, standard deviation, and coefficient of variation from the performance of the Nile tilapia larvae subjected to different liming products for 30 days.

| | Weight (g) | Total length (cm) | Standard length (cm) | Fulton condition factor |
|---|---|---|---|---|
| Water | 3.63±0.22 | 2.86±0.23 | 0.73±0.19 | 15.83±2.86 |
| Calcitic | 3.54±0.08 | 2.72±0.12 | 0.59±0.09 | 17.66±1.90 |
| Dolomitic | 3.70±1.54 | 2.89±1.20 | 0.76±0.42 | 16.38±5.23 |
| Soil | 3.65±0.19 | 2.84±0.14 | 0.77±0.16 | 16.01±1.45 |
| Silicate | 3.61±0.16 | 2.83±0.13 | 0.67±0.10 | 15.92±1.73 |
| CV (%) | 7.76 | 8.73 | 30.13 | 19.56 |
| | Weight gain (g) | Biomass (g) | Biomass gain (g) | Survival (%) |
| Water | 3.61±0.22 | 50.23±9.53 | 49.93±9.53 | 92.0±16.0 |
| Calcitic | 3.52±0.08 | 51.05±2.17 | 50.75±2.17 | 96.0±3.26 |
| Dolomitic | 3.68±0.47 | 43.49±19.26 | 43.19±19.26 | 64.0±44.54 |
| Soil | 3.63±0.19 | 50.55±6.47 | 50.25±6.47 | 92.0±9.79 |
| Silicate | 3.59±0.16 | 51.37±5.06 | 51.37±5.06 | 94.6±7.77 |
| CV (%) | 7.8 | 22.19 | 22.32 | 20.92 |

In the same column, means did not differ, according to the Tukey test, at 0.05 probability.

The pH was higher ($p<0.05$) in the silicate and calcitic treatments than in the control, and the others did not differ from each other. For the redox potential, the dolomitic treatment was higher ($p<0.05$) than in the soil, and the others did not differ from each other. The electrical conductivity was higher ($p<0.05$) in the soil treatment than in the control, and the others did not differ from each other. The turbidity in the soil was higher ($p<0.05$) than in the other treatments.

Table 3. Mean values, standard deviation, and coefficient of variation of the water quality of Nile tilapia larvae culture subjected to different liming products for 30 days.

| | pH | ORP (mV) | Conductivity (mS $cm^{-1}$) | Turbidity (NTU) |
|---|---|---|---|---|
| Water | 7.47 ±0.49c | 190.4±47.47ab | 0.20±0.01b | 169.1±111.66b |
| Calcitic | 7.97±0.28a | 162.9±41.34ab | 0.21±0.00ab | 209.1±98.99b |
| Dolomitic | 7.81±0.37ab | 194.8±62.55a | 0.21±0.00ab | 163.7±136.89b |
| Soil | 7.58±0.42bc | 156.0±21.42b | 0.35±0.02a | 355.1±214.51a |
| Silicate | 8.09±0.38a | 170.6±49.12ab | 0.28±0.00ab | 164.0±186.91b |
| CV (%) | 3.81 | 20.83 | 35.42 | 66.21 |

Means followed by different letters in the columns differ, using the Tukey test, at 0.05 probability. ORP= oxidation reduction potential.

Salinity was higher ($p<0.05$) in treatments that received liming products but with low values. Ammonia was higher ($p<0.05$) in the control treatment than in the treatment with silicate, and the others did not differ from each other. Nitrite and nitrate concentrations did not differ ($p>0.05$) between treatments.

Table 4. Mean values, standard deviation, and coefficient of variation of the water quality of Nile tilapia larvae culture subjected to different liming products for 30 days.

| | DO (mg $L^{-1}$) | Salinity (‰) | Ammonia (mg $L^{-1}$) | Nitrite (mg $L^{-1}$) | Nitrate (mg $L^{-1}$) |
|---|---|---|---|---|---|
| Water | 4.8±0.73a | 0.00±0.00b | 0.03±0.03a | 0.16±0.27a | 0.17±0.33a |
| Calcitic | 4.7±0.66a | 0.01±0.00ab | 0.02±0.02ab | 0.14±0.25a | 0.18±0.25a |
| Dolomitic | 6.6±4.75a | 0.01±0.00a | 0.02±0.03ab | 0.09±0.16a | 0.11±0.31a |
| Soil | 4.7±1.05a | 0.00±0.00b | 0.02±0.02ab | 0.07±0.18a | 0.02±0.08a |
| Silicate | 4.8±0.81a | 0.01±0.00a | 0.01±0.01b | 0.02±0.06a | 0.05±0.12a |
| CV (%) | 45.74 | 39.47 | 65.17 | 192.31 | 187.25 |

Means followed by distinct letters in the column vary by Tukey's test at 0.05 probability. ns Not significant. * Significant by Tukey's test at 0.05 probability. DO = Dissolved oxygen.

Alkalinity was higher ($p<0.05$) in the silicate treatment and did not differ among the others. Hardness was higher ($p<0.05$) in the calcitic, dolomitic, and silicate treatments to the control and soil. Calcium dissolved in water was higher ($p<0.05$) in the calcitic and silicate treatments than in the control and soil. Silica dissolved in water was higher ($p<0.05$) in silicate.

Table 5. Mean values, standard deviation, and coefficient of variation of the water quality of Nile tilapia larvae culture subjected to different liming products for 30 days.

| | Alkalinity (mg $L^{-1}$) | Hardness (mg $L^{-1}$) | Calcium (mg $L^{-1}$) | Magnesium (mg $L^{-1}$) | Silica (mg $L^{-1}$) |
|---|---|---|---|---|---|
| Water | 48.80±17.84b | 39.3±22.45b | 27.6±20.09b | 11.6±8.31a | 0.01±0.00b |
| Calcitic | 52.27±20.64b | 84.74±27.13a | 70.3±31.14a | 11.6±10.28a | 0.01±0.01b |
| Dolomitic | 52.73±19.30b | 69.3±31.21a | 53.3±23.09ab | 16.0±19.35a | 0.01±0.00b |
| Soil | 51.27±24.20b | 37.0±14.36b | 26.3±11.33b | 10.6±7.27a | 0.01±0.01b |
| Silicate | 67.27±25.59a | 90.7±39.48a | 79.07±35.95a | 14.3±13.16a | 0.30±0.01a |
| CV (%) | 22.54 | 21.24 | 22.65 | 80.96 | 29.95 |

Means followed by distinct letters in the column vary by Tukey's test at 0.05 probability. ns Not significant. * Significant by Tukey's test at 0.05 probability.

## DISCUSSION

### Larval performance

Larval performance and survival did not differ according to the liming products. Although these products provided differences in water quality parameters, they remained within the range considered suitable for the cultivation of larvae[14-16] and juveniles[17,18] of the species, which explains the similarity in animal performance between the treatments tested.

## Water quality

Water quality is the most critical factor affecting the health and performance of fish in production systems. They depend on the water they live in, which makes it necessary to understand the water quality conditions required by fish[19].

The temperature (30 °C) maintained by the heaters was similar between treatments and within the suitable range for the species. Studies report that the appropriate range varies from 20.2 to 31.7°C, with the ideal temperature being 26.0°C[20], with the highest growth rates observed at 26 and 30 °C[21] and 28 and 34°C[22].

Throughout the period, aeration maintained similar dissolved oxygen levels between treatments and within the range (5 to 6 mg $L^{-1}$) considered adequate for the survival and growth of Nile tilapia[23-25] and for tropical species[26].

The redox potential (ORP) showed averages between 156.0 and 194.8 mV, close to values considered adequate for tilapia cultivation in a biofloc system, 155.33 mV[27]. The redox potential values of this experiment are consistent with the oxygen concentrations, which were maintained at constant rates (> 4.7 mg $L^{-1}$) and with the pH (7.47 to 8.09) associated with periodic cleaning to remove organic matter. Pond management influences the behavior of the redox potential, and knowing the potential profile can help understand the welfare and immunity of animals[28]. A high and positive redox potential generally indicates an oxidizing environment, rich in oxygen and more suitable for aquatic organisms, while an environment with negative values indicates reducing water[27-29]. Under high redox values, conditions are usually favorable for bacteria to decompose organic matter and contaminants more efficiently[30]. Several factors interact and interfere with the redox potential, such as the distribution in the water column, whether closer to the surface or the sediment-water interface, and factors such as the decomposition of organic matter and the metabolism of microorganisms, which decrease the potential, among others[29]. Therefore, the oxidation-reduction potential conditions were favorable to tilapia in all treatments due to this experiment's relatively homogeneous environments, with constant oxygenation, water renewal, and periodic cleaning in a reduced space.

Even though the initial phases of tilapia are more susceptible than adult specimens to changes in pH[31,32] the narrow pH range observed in this experiment was favorable to the well-being and development of the species, which can be measured by the survival values found.

The water in the aquariums without the addition of products and with soil at the bottom that did not receive liming products had a slight pH fluctuation, as in the other treatments, due to the alkalinity of their waters (48.80 and 51.27 mg $L^{-1}$, respectively). The pH keeping occurs because alkalinity has a buffering effect that minimizes fluctuations in water pH, avoiding stress in fish, with the minimum values suggested for aquaculture being 20 mg $L^{-1}$ $CaCO_3$ of alkalinity[6] to 40 mg $L^{-1}$ $CaCO_3$[33]. Soil aquariums could present low pH and alkalinity, being susceptible to sudden changes in pH since the soil is usually a source of acidity due to aluminum ions, clay, and negatively charged organic matter particles, attracting cations to their surfaces, in addition to low concentrations of bicarbonate, carbonate, calcium, and magnesium[34], which was not observed in this experiment, in which the pH of the water, in the various treatments, ranged from 7.5 (water) to 8.1 (silicate), being within the range considered suitable for the growth of larvae[14,35,36] and juveniles[37] of Nile tilapia.

The alkalinity of this experiment presented an adequate range with slight oscillation (48.80 to 67.27 mg $L^{-1}$), which explains why no difference was observed in larval growth. The values were almost similar for all treatments except for silicate, which were slightly higher.

Although waters with higher alkalinity tend to have higher fish production due to the more significant buffering effect, with less fluctuation in pH[4], the results depend on the alkalizing product[8,9] and the adequate concentration, for each species and stage of development[31,38].

The values were similar to those found in the culture of Nile tilapia larvae, which grew more when subjected to 32 mg $L^{-1}$ of $CaCO_3$ than to 15 or 55 mg $L^{-1}$ of $CaCO_3$[31]. The alkalinity levels were also similar to those observed in the culture of tilapia juveniles in bioflocs in which sodium bicarbonate ($NaHCO_3$ 75.76 mg $L^{-1}$), calcium carbonate ($CaCO_3$ 49.95 mg $L^{-1}$) or calcium hydroxide ($Ca(OH)_2$ 54.58 mg $L^{-1}$) were used, in which the juveniles presented greater weight when subjected to the highest alkalinity (75.76 mg $L^{-1}$), and worse in the lowest (49.95 mg $L^{-1}$), a difference that was associated with a change in management due to the characteristics of the alkalizing agents[9]. The survival (91.0%) of the fish was similar to that found for Nile tilapia (88.3%) subjected to different alkalinities (9.2, 15.5, 30.8, 73.0, and 90.4 mg $L^{-1}$) obtained by other products ($CaCO_3$, $Na_2CO_3$ or $CaSO_4$) where the increase in alkalinity by $CaSO_4$ provided a negative effect[39]. The values observed in this experiment, adding the values of the studies above, indicate that the alkalinity was within the range suitable for the growth of Nile tilapia larvae.

Despite the lower hardness levels observed in aquariums without products (control) and in soil, the hardness range in this experiment was within that considered adequate for the species[39-41], which generated similar animal performance between treatments. Water hardness increases the antioxidant response, reduces the toxicity of some substances, the loss of ions, buffering the environment and favoring fish development[42-45]. Nile tilapia juveniles perform better when total hardness is greater than 20 mg $CaCO_3$ $L^{-1}$ [39], and when water hardness is less than 25 mg $L^{-1}$, limestone should be applied[46]. Since the water used in the experiment initially had 17 mg L-1 and increased in the control treatment, which was only water, calcium in the feed helped to increase hardness. The initial hardness required the application of the alkalizing agent. Increased hardness and decreased alkalinity in closed aquaculture systems have been reported[47].

Regarding calcium, a higher amount occurred in the treatments that received liming products, similar to that observed by Antonangelo et al.[48]. However, even the control and soil group showed an increase in the amount of calcium dissolved in the water compared to the first day of collection due to the calcium in the feed offered to the fish, as observed in the cultivation of cachama blanca, *Piaractus brachypomus* in a recirculation system, where hardness increased[49]. Magnesium, on the other hand, was not added enough to provide a significant difference, unlike that observed by Antonangelo et al.[48].

Calcium and magnesium ions are essential for water hardness and alkalinity[6] and ionic regulation in freshwater fish[39]. Aquatic animals have unique physiological mechanisms to absorb and retain minerals, such as calcium, magnesium, and phosphorus, through their diets and directly from water, through gill and skin absorption, with excessive intake or deficiency being harmful to fish[50,51]. Magnesium deficiency causes skeletal deformities, cardiovascular diseases, and metabolic syndrome[52], such as nephrocalcinosis[51], damage to the structural integrity of the intestine, suppressing fish growth[53]. Calcium deficiency compromises skeletal formation[54], resulting in fish with deformities[50].

Excess is also a problem, as high levels of calcium (31.0 g $kg^{-1}$ of feed) in the diet of Japanese sea bass, *Lateolabrax japonicus*, significantly reduced weight, weight gain, feeding rate, specific growth rate, whole-body and muscle protein and lipid contents, as well as serum Ca concentration and alkaline phosphatase activity. There was even a significant reduction in the vertebral contents of Ca, P, Zn, Fe, and Mn and the contents of Ca, P, Mg, and Mn in scales, leading to a higher rate of fish deformation[50]. It is also worth noting that magnesium helps to activate vitamin D, which helps to regulate calcium and phosphate homeostasis, which influences bone growth and maintenance[52].

As no deformities were observed and growth was equal between treatments and within expectations, calcium and magnesium levels were adequate for tilapia larvae.

The higher concentration of silica in water with added silicate was expected, as also observed by Emerenciano et al.[55]. Silica is the second most abundant component in the Earth's crust, making up the silicate of rocks that dissolve in natural waters[56]. However, due to the low solubility of this mineral, these waters generally have low alkalinity and total hardness, both in surface waters and aquifers composed of sand and/or silicate minerals[7]. However, when in the form of calcium silicate ($CaSi0_3$) or sodium silicate ($Na_2Si0_3$), the solubility is sufficient for this material to be used for liming, neutralizing the hydrogen ion, in addition to serving as a source of silica for diatoms[7,56], which increase their population, improving shrimp growth performance, inhibiting pathogenic vibrios, increasing the profit of the activity[55].

Calcium-magnesium silicate was promising as a promoter of a stable environment for tilapia larvae culture, as it allowed suitable water quality parameters, in addition to the development and survival being similar to those of tilapia larvae grown in waters with calcium carbonate and calcium and magnesium carbonate, known to be suitable for fish farming[7]. The results of the larvae in water with silicate were also similar to those kept in water with soil, an element that makes up the natural environment of tilapia. Menezes et al.[57] obtained similar results in the yield and survival of tilapia juveniles subjected to water with the addition of calcium silicate, dolomitic limestone and calcitic limestone, as well as de Souza et al.[8] obtained similar results in the yield and survival of jundiá *Rhamdia quellen* juveniles subjected to water with the addition of sodium silicate, sodium bicarbonate and calcium carbonate.

Agronomic studies also reinforce the findings regarding water quality in this experiment, where calcium and magnesium silicate significantly increased pH, calcium, magnesium, and silicon, reducing the elements that promote acidity[48]. Other results evaluating calcium and magnesium silicate prove the high power of neutralizing soil acidity when compared to dolomitic limestone[58] and that calcium silicate is 6.8 times more soluble than calcium carbonate, favoring the correction of acidity[59].

The electrical conductivity was within the acceptable range, 1000 μS $cm^{-1}$, for fish farming[6]. The conductivity of the water in aquariums with soil was significantly higher than that of aquariums with only water. The others were similar to all.

Tank soils interact with water, altering its characteristics[60]. Soil conductivity results from its composition, with soils richer in clay and smaller particles with higher conductivity than sandy soils[61]. Therefore, the soil's presence explains the water's higher conductivity.

However, despite increasing the electrical conductivity of the water[62,63], the different liming products did not increase the conductivity compared with the control treatment (water only). High conductivities can also be related to a large amount of organic matter in the water, usually from the feed[64]. Waters rich in phosphate, among other nutrients, generally have a higher conductivity, which could make the electrical conductivity of the water an indicator of eutrophication[61]. However, the amount of nutrients added by the feed was similar between treatments, justifying the high conductivity values and the similarity of the results.

The turbidity of the soil treatment was higher than that of the others, which the suspension of sediment particles can explain. Suspended clay is responsible for much of the turbidity of the water in fish ponds[65].

Turbidity has been considered a problem in the cultivation of Nile tilapia juveniles[9,65,66] when it affects fish development[9,66], and even when it does not interfere[65]. The increase in turbidity can also be caused by liming products added to the environment[9,67], although it did not increase turbidity in this experiment. Although tilapia do not suspend much clay from the bottom of excavated tanks[66], they increase turbidity by suspending particles from the bottom of the tank in this intensive system due to the fish swimming in environments with reduced space.

Total ammonia concentrations were low and within the comfort range for cultivating tilapia larvae[14,36].

Considering that Nile tilapia larvae did not have their growth and survival compromised when subjected for 80 days after hatching to a concentration of 0.25 mg $L^{-1}$ of non-ionized ammonia, becoming affected at 0.45 mg $L^{-1}$ [68], and the average $LC_{50}$ value at 48 h was 1,009 mg $L^{-1}$ for the larvae[69], the ammonia concentration was within the adequate range for Nile tilapia larvae.

As with ammonia, nitrite and nitrate concentrations were similar to the values considered adequate for raising Nile tilapia larvae[14,36], and were below the concentrations considered safe limits for fish farming, which are 0.5 mg $L^{-1}$ and 4.5-5.0 mg $L^{-1}$ of nitrite and nitrate, respectively[70, 71] or even of the ideal concentrations of 0.3 mg $L^{-1}$ and 25.0 mg $L^{-1}$ of nitrite and nitrate, respectively[72].

Although these limit values exist, the nitrite level considered comfortable varies with the species, stage of development, and interactions with other water parameters. For juveniles of the yam *Cichlasoma facetum*, a cichlid like tilapia, the safety limit is 7.0 mg $L^{-1}$ [73], while for juveniles of *Rhamdia quelen*, the adequate limit that does not compromise growth and survival is 1.19 mg $L^{-1}$ [74]. Rainbow trout gets stressed by 0.15 mg $L^{-1}$ of nitrite and die by 0.55 mg $L^{-1}$. Channel catfish are more resistant to nitrite, starting to die at 29 mg $L^{-1}$. However, water should be checked whenever 0.1 mg $L^{-1}$ or more of nitrite is present[73]. Although nitrite values in the aquariums with only water (0.16 mg $L^{-1}$) and in the calcitic limestone (calcium carbonate – 0.14 mg $L^{-1}$) were above 0.1 mg $L^{-1}$, they were adequate for the species.

The low values of nitrogen compounds explain why the alkalinities did not change much. The nitrification process by bacteria reduces alkalinity by releasing H+ ions into the water[47], while the oxidation of 1 mg $L^{-1}$ of ammonia reduces alkalinity by 7.14 mg $L^{-1}$ [7]. Therefore, the low nitrogen compound concentrations resulted in low alkalinity consumption, which remained within a range suitable for Nile tilapia larvae.

The salinity variation was slight and remained within the range considered freshwater when the salinity is less than 1‰[75]. The early life stages of Nile tilapia are euryhaline. Although low salinities negatively affect hatching rates, survival, and yolk sac absorption, larvae six days after hatching tolerate salinities of up to 20‰[76]. Since Nile tilapia tolerate salinities from 7‰[77] to 22.5‰[78] and can be cultured in waters with up to 30‰, if properly acclimated and fed[79], the salinities were adequate for larval development.

## CONCLUSION

Calcium-magnesium silicate is a viable and recommended alternative for liming, as it presents results equivalent to calcitic and dolomitic limestone, traditional salts for this practice, which confirms its importance in maintaining water quality and fish performance. Although the soil has a buffering capacity in the water, it is less effective than other products and deserves further study.

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