

Evaluation of the effectiveness of a biological filter in improving water quality in commercial fish farming

Avaliação da eficácia de um filtro biológico na melhoria da qualidade da água em piscicultura comercial

Evaluación de la eficacia de un filtro biológico en la mejora de la calidad del agua en la piscicultura comercial

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Abstract

The objective was to evaluate the efficiency of using biological filters in commercial fish farming on the physical-chemical parameters of the water. The system was built and tested in a commercial fish farm in a tank containing 69,137.1 L of water. The filter system was composed of settling tanks, root zones, a media area, equalizer, and probiotic tank. The plants used were Mururu (*Eichornia crassipes*), Cattail (*Typha domingensis*), and duckweed (*Lemna minor*). The physicochemical analyses corresponded to the following parameters: pH, dissolved O₂, hardness and total alkalinity, chlorides, conductivity, total dissolved solids, turbidity, nitrate, nitrite, aluminum, manganese, ammonia N, orthophosphate, sulfide, zinc, residual chlorine, chromium, aluminum, total phosphorus, and iron. Statistical differences ($P < 0.05$) were observed for the variables: pH, temperature, dissolved O₂, total hardness, turbidity, nitrate, nitrite, ammonia N, residual chlorine, chloride, conductivity, and phosphorus, demonstrating the efficiency of the biological filter for improving water quality. Therefore, the biological filter promoted the expected benefits, improving the water quality in the commercial pond.

Palavras-chave: Biological Filter; Fish Farming; Sustainability; Water Quality.

Resumo

Objetivou-se avaliar a eficiência do uso de filtro biológico em piscicultura comercial sobre os parâmetros físicos-químicos da água. O sistema foi construído e conduzido em piscicultura comercial em tanque de 69.137,1 L de água. O sistema de filtros foi composto por tanques de decantação, zonas de raízes, área de mídias, equalizador e tanque de probiótico. As plantas utilizadas foram Mururu (*Eichornia crassipes*) e Taboa (*Typha domingensis*) e lentilhas de água (*Lemna minor*). As análises físico-químicas corresponderam aos seguintes parâmetros: pH, O₂ dissolvido, dureza e alcalinidade total, cloretos, condutividade, sólidos totais dissolvidos, turbidez, nitrato, nitrito, alumínio, manganês, N amoniacal, ortofosfato, sulfeto, zinco, cloro residual, cromo, alumínio, fósforo total e ferro. Houve diferença estatística ($P < 0,05$) para as variáveis: Ph, temperatura, O₂ dissolvido, dureza total, turbidez, nitrato, nitrito, N amoniacal, cloro residual, cloreto, condutividade e fósforo, demonstrando a eficiência do filtro biológico em melhorar a qualidade da água. Portanto, o filtro biológico promoveu os benefícios esperados, melhorando a qualidade da água do viveiro comercial.

Keywords: Filtro Biológico; Piscicultura; Sustentabilidade; Qualidade de Água.

Resumen

El objetivo fue evaluar la eficiencia del uso de filtros biológicos en la piscicultura comercial sobre los parámetros físico-químicos del agua. El sistema fue construido y llevado a cabo en piscicultura comercial en un tanque con 69.137,1 L de agua. El sistema de filtrado estuvo compuesto por tanques de sedimentación, zonas de raíces, área de medios, equalizador y tanque de probióticos. Las plantas utilizadas fueron Mururu (*Eichornia crassipes*) y Totora (*Typha domingensis*) y lenteja de agua (*Lemna minor*). Los análisis fisicoquímicos correspondieron a los siguientes parámetros: pH, O₂ disuelto, dureza y alcalinidad total, cloruros, conductividad, sólidos disueltos totales, turbidez, nitrato, nitrito, aluminio, manganeso, N amoniaco, ortofosfato, sulfuro, zinc, cloro residual, cromo, aluminio, fósforo total y hierro. Hubo diferencia estadística ($P < 0,05$) para las variables: Ph, temperatura, O₂ disuelto, dureza total, turbidez, nitrato, nitrito, N amoniaco, cloro residual, cloruro, conductividad y fósforo, demostrando la eficiencia del filtro biológico en mejorando la calidad del agua. Por lo tanto, el filtro biológico promovió los beneficios esperados, mejorando la calidad del agua en el estanque comercial.

Palabras clave: Filtro Biológico; Piscicultura; Sostenibilidad; Calidad del Agua.

Introduction

The year 2022 marked another milestone for Brazilian aquaculture, with cultured fish production reaching 860,355 tons, as reported by the Brazilian Association of Fish Farming (Peixe BR). This represents a 2.3% increase from the previous year with 841,005 tons, showcasing the industry's steady growth. The data on Peixe BR (2023) reveal an impressive 48.6% expansion in cultured fish production over nine years, indicating significant progress in the sector. This growth is attributed to advancements across the entire production chain, driven by a commitment to sustainability and increased consumer demand. Tilapia (*Oreochromis niloticus*) remain the cornerstone of Brazilian fish farming, accounting for 63.9% of the total cultured fish production in 2022, surpassing the 550,000-ton mark, representing a 3% increase compared to 2021, and underscoring its continued dominance in the industry.

Improving the infrastructure and maintaining a balance between production and environmental preservation are paramount for the progress of Brazilian aquaculture (Silva *et al.*, 2013; Silva *et al.*, 2018). To address water quality concerns and optimize fish welfare, health, and performance, the development of wastewater treatment systems is imperative (Ge *et al.*, 2016; Nakayama *et al.*, 2022). In this context, high-density fish production, characterized by substantial feed input (usually 1-5% of biomass), generates waste and poses challenges related to fluctuations in parameters such as dissolved oxygen (DO), ammonia (NH₄/NH₃), nitrite (NO₂), carbon dioxide (CO₂), pH, water pollution, temperature, salinity, and hardness (Queiroz *et al.*, 2021).

Furthermore, optimal water quality, achieved through circulation systems, allows for increased biomass production per cubic meter. However, effective treatment of reused water requires documentation of systems to evaluate the efficiency of infiltration systems as an alternative to biological purification methods. The efficacy of this approach diminishes in the presence of suspended solids or organic matter (Michael-Kordatou *et al.*, 2015; Al-Ghouti *et al.*, 2019). The selection of wastewater treatment methods depends on effluent standards, water quality, flow rate, and economic considerations.

The Recirculating Aquaculture System (RAS) is a method designed to enhance water quality for reuse within the system in super-intensive fish farming. This system employs mechanical and biological filters to treat circulated water (Kubitza, 2006), whereby the water passes through various components, such as settlers, mechanical filters, and biological filters, which remove solid materials like excess feed, feces, and waste. Within the biological filter, nitrifying bacteria from the Nitrosomonas family regulate ammonia levels, while Nitrobacter bacteria reduce nitrite levels (Wagner *et al.*, 2019; Baskaran *et al.*, 2020; Burut-Archanai *et al.*, 2021).

An efficient method used as a biofilter involves the use of media for the development of microorganisms that are effective in reducing organic matter and ammonia (N-NH₄), converting organic matter into CO₂ and ammonia into N₂. The process occurs through infiltration by percolation through a natural soil profile or separate filters containing natural or engineered porous media (Guerra *et al.*, 2019; Brooks *et al.*, 2020).

Both infiltration and filter systems are engineered to serve as biological filters, facilitating purification via physical filtration, chemical reactions, and biological transformations (Grebel *et al.*, 2013; Jayakumar *et al.*, 2021; Saravanan *et al.*, 2021). Well-designed biofilters can yield high-quality effluents when treating effluents. Therefore, the aim of the current study was to assess the effectiveness of employing a biological filter in aquaculture to improve the water quality of a suspended commercial breeding pond.

Material and method

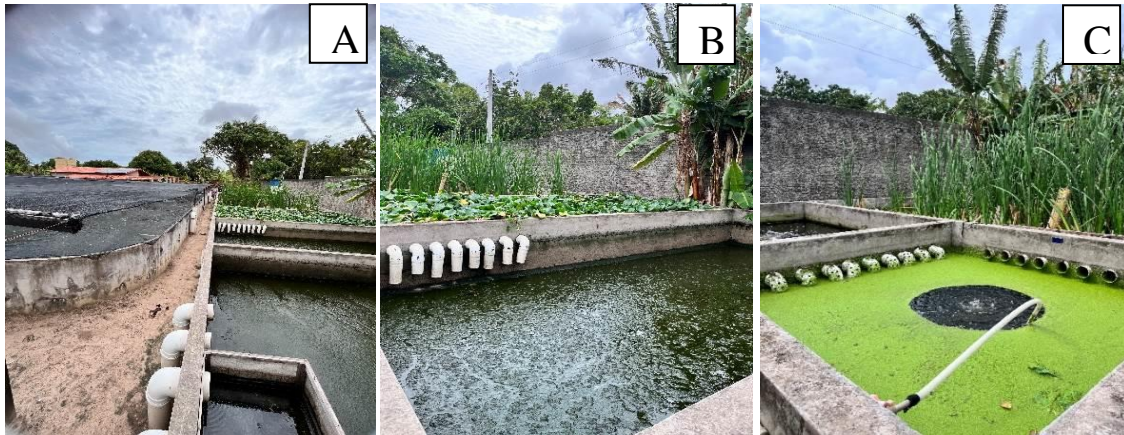
The experiment was conducted at Piscicultura Arouche, located in Vassoural, Paço do Lumiar, in the eastern region of the state of Maranhão. The geographical coordinates are Latitude: -2.53054 and Longitude: -44.1052, corresponding to 2°31'50" South and 44°6'19" West. The study was conducted from December 2022 to January 2023. According to the Thorntwaite-Mather classification, the climate of the area is categorized as B3, falling under the tropical climate domain, characterized by a humid summer and a dry winter period. The region experiences a dry spell lasting approximately five months (from June to December), with an average annual precipitation of 2,283 mm and an average annual temperature of 27.5°C (Clima Today - INMET, 2023).

The system was set up and operated within a commercial tilapia (*Oreochromis niloticus*) fishery, housed in a tank with a capacity of 69,137.1 liters of water, 2.35 hp aeration equipment (blower) for the cultivation tank and a 1.75 hp blower for the media area tank. The tank was covered with 50% transparent shade netting. The external walls of the tank are 1.20 meters high, with the water level maintained at 1.00 meter and a 25 cm difference in water drainage levels between tanks.

During July 2022, seven biological filters were installed, consisting of interconnected masonry tanks with capacities of 7,000 L (1st settler, 2nd settler, 1st root zone, 2nd root zone), 3,500 L (2 clay expanded tanks, media area), and 12,000 L (equalizing tank). Water Hyacinth (*Eichornia crassipes*) and Cattail (*Typha domingensis*) were planted in the root tanks, while media was used in the tank under constant mechanical aeration. PVC

pipes, each measuring 100 inches, were utilized to connect each compartment of the filter system, facilitating the flow from one compartment to another (Figure 1).

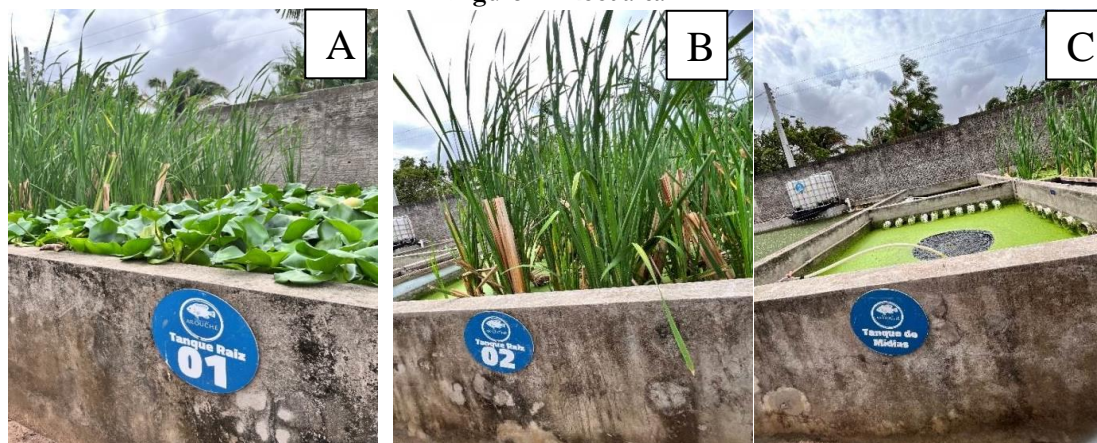
Figure 1 - Filter system interconnected by 100-inch PVC pipes.



Legend: A. Area view of tanks, B. Settling tank, and C. Tank for media area with clay, *Lemna Minor* plant, and constant aeration (1.75 hp blower). Source: Jéssica Antonia Cardoso Mendes (2024).

For constructing the filters, masonry walls measuring 120 cm in height were utilized, with flanges installed on the tanks and reservoirs to accommodate the 50-inch pipes, effectively connecting the filter to the reservoir (Figure 2).

Figure 2 - Root area

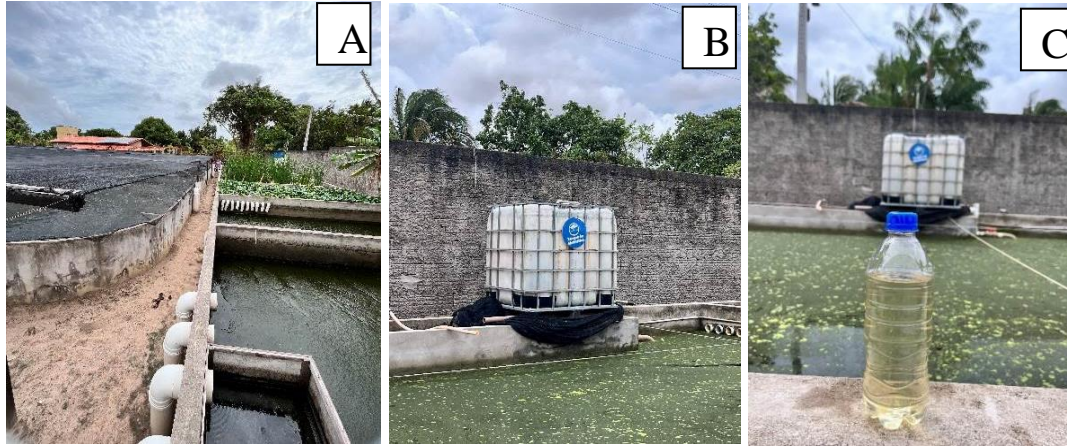


Legend: A. Root tank plant Mururu; B. Root tank plant Taboa; C. Media tank with nitrifying bacteria under direct aeration and *Lemna Minor* plant. Source: Jéssica Antonia Cardoso Mendes (2024).

The system contains a probiotic tank. The probiotic Dbaqua was used, dissolved in water, at 2 g/m³. After dissolution, the water treated with the probiotic was left for 24 hours before being placed in the water from the return tank to the recirculation system for the cultivation tanks. This is the last water treatment tank through which water flows, to stabilize pH and dissolved oxygen levels, enhance the carbon-to-nitrogen balance, and

foster bacterial colony bio-reactors, among other functions before the water is deemed suitable for reintroduction into the system (Figure 3).

Figure 3 - Biofilter and probiotic tank.



Legend: A. General view of the cultivation tank (left side) and filter system on the right of the image; B. Symbiotic and filtered water storage tank; C. Presentation of water after passing through the system filters.

Source: Jéssica Antonia Cardoso Mendes (2024).

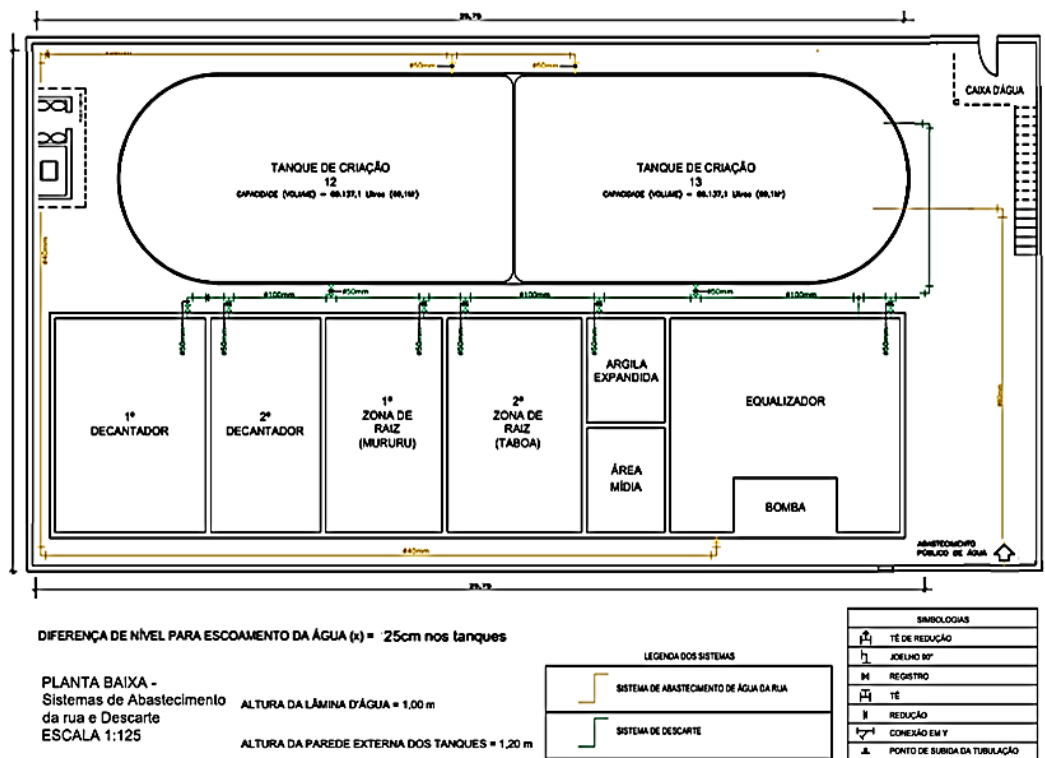
In September de 2022, fingerling stocking commenced in the reservoirs of the suspended tank system at a density of 60 fingerlings/m³ within the 69,137.1 L cultivation reservoir. Additionally, a pump capable of circulating 1,200 liters per hour was installed in the cultivation tank. This pump was connected to a timer set to recirculate the water every 15 minutes. The water from both the tank and the filter underwent laboratory evaluation for physicochemical monitoring during the 60 days after the stocking. For the analysis, a 500 ml sample was collected from the water in the suspended tank containing the fish, and another 500 ml sample was taken after passing through all the components of the filter and undergoing mechanical and biological action. Sampling occurred every 15 days over a period of 60 days, with all collections performed at 10 a.m. The structural design of the tanks and filters is depicted (Figure 4).

For analysis of the physical, chemical, and biological variables, samples were collected using a Van Dorn bottle and transferred to 1 L polyethylene bottles, which were then transported to the laboratory. Dissolved oxygen content (mg/L) and water temperature (°C) were measured using a mercury bulb thermometer, graduated from 0 to 50°C. Additionally, the dissolved oxygen content in the water was assessed using a pH meter.

The physical-chemical analyses were conducted at the Food and Water Physicochemical Laboratory of the State University of Maranhão. These analyses included pH, total hardness, total alkalinity, chlorides, conductivity, total dissolved solids (TDS), and

turbidity. The laboratory employed the analytical methods outlined in the Analytical Standards Book of the Adolfo Lutz Institute (Zenebon; Pascuet, 2005; American Public Health Association; American Water Works Association Water; Environment Federation, 1995).

Figure 4 - Filter System Floor Plan.



Legend: Tank supply system with well water, and treatment of fish farming effluents with biological filters through physical, chemical, and biological processes. Source: Jéssica Antonia Cardoso Mendes (2024).

For physical-chemical determinations, samples were collected in a first-use mineral water bottle, with its original lid. The bottle and its lid were washed three times with distilled water. After collection, the lid was secured to prevent leaks and the samples were identified, before being immediately transported to the laboratory under refrigeration. The analyses began two hours after collection of the water samples.

The determination of nitrite and nitrate occurred simultaneously. This method can be applied to simple additive formulations containing nitrites, nitrates, and sodium chloride. The ratio of the absorbances of an aqueous nitrite solution at 355 nm and 302 nm is 2.5. Nitrate does not absorb at 355 nm, but has a characteristic band at 302 nm. The nitrate absorbance is calculated by dividing the nitrite absorbance at 355 nm by 2.5 and subtracting the quotient from the total absorbance at 302 nm. In a 1 cm cuvette, the detection limit for nitrite is 0.02 mg/mL and for nitrate is 0.09 mg/mL. The pH of the

solution must not be below 5 (nitrite forms nitrous acid, with a maximum absorbance at 357 nm).

The pH was evaluated using the electrometric method, utilizing a precise Phmetro device (Asko brand) with automatic calibration and a digital reader. Dissolved Oxygen, salinity, electrical conductivity, and temperature were evaluated using the multiparameter meter + Dissolved Oxygen Probe (Asko brand, model Ak87).

Nitrogenous ammonia was determined by the spectrophotometric method. For this, Nessler's reagent was used, which reacts, when added to a diluted ammonia solution, forming a yellowish compound, which can flocculate after a certain time. The ammonia concentration is determined using the standard curve established with standard ammonium chloride solutions, the result was multiplied by 0.5, as an aliquot of 50 mL was taken from a volume of 250 mL containing 200 mL of distillate from 500 mL of the sample. To express the result in ammonia nitrogen, the result obtained for ammonia was multiplied by 0.824.

The total solids, suspended or dissolved matters present in the water sample, were determined by checking the mass of the residue of the water samples, after evaporation and drying until constant weight, at 103 to 105°C.

A clean porcelain capsule was heated in an oven at 105°C for 3 hours, before being transferred to a desiccator, until reaching room temperature, and then weighed. Following this, 100 mL of the unfiltered water sample were placed in a volumetric flask and quantitatively transferred to the previously weighed capsule. The water sample was evaporated until dry in a water bath (37°C) and the capsule was then placed in an oven at 10°C for 3 hours. After this period, the capsule was placed in a desiccator, allowing it to reach thermal equilibrium with the environment and weighed. The operations were repeated until a constant weight was obtained or until the weight difference was less than 4% of the previous measurement. Determinations were performed in duplicate.

The determination of turbidity was evaluated by the turbidimetric method, using Hellige Turbidimeter equipment. The turbidity range was chosen and the appropriate filter was selected. After cleaning, the turbidimeter cell with the appropriate height for the chosen turbidity range was carefully dried. The cell was filled to the mark with the sample. The plunger was cleaned by carefully immersing it in the liquid that fills the cell, to avoid bubbles. The outside of the cell was cleaned, and then the cell was placed on the mirrored platform. The appliance door was closed and the light turned on. The intensity of the light from the central beam was immediately balanced with the intensity of the background, reading the graduated scale on the button disc when the brightness of the two fields was balanced. Turbidity was determined with the graph appropriate to the operating range used

(American Public Health Association; American Water Works Association Water; Environment Federation, 1995).

Iron determination was carried out using a UV/VIS Spectrophotometer. The sample was shaken, and 50 mL were transferred to a 250 mL beaker, 4 mL of 50% HCl (v/v) and 1 mL of 10% hydroxylammonium chloride solution (m/v) were added. The mixture was boiled until the volume reduced to 20 mL and was then left at room temperature until it cooled. Then, 5 mL of acetate buffer and 2 mL of phenanthroline solution were added and the solution was transferred to a 50 mL volumetric flask. The walls of the beaker were washed, and the volume was completed with distilled and deionized water. Subsequently, the solution was homogenized and left to rest for 15 minutes, for complete color development. For the absorbance analysis, the spectrophotometer was zeroed with the test blank, then the absorbance of the water sample was evaluated.

The determination of total hardness was defined as the sum of the concentrations of calcium and magnesium, both expressed as calcium carbonate, in milligrams per liter. Ethylenediaminetetraacetic acid and its sodium salts (EDTA) form soluble chelated complexes with certain metal cations. A solution containing calcium and magnesium ions, with a small amount of the black indicator eriochrome T, turns purple at pH (10.0±0.1). By titrating this solution with EDTA, calcium and magnesium were chelated and a purple to blue color change indicated the end point. Then 50 mL of the sample were transferred to a 250 mL Erlenmeyer flask, and 1 mL of the buffer solution and a small portion (0.05 g) of the black eriochrome T indicator were added. The solution was titrated with the 0.01 M EDTA solution until the purple color changes to blue.

Equation (total hardness)

$$TH = 1000 \times v \times A/V$$

v = number of mL of EDTA solution used in the titration

A = mg of CaCO₃ equivalent to 1 mL of 0.01 M EDTA solution

V = sample mL number

Other analysis methodologies for aluminum, sulfide, chromium, total phosphate, orthophosphates, sodium chloride, total dissolved chloride, residual chlorine, and zinc were performed using the colorimetric technique, following the procedure recommended by the manufacturer Alfacit. All analyses were carried out in duplicate. The filters had been in continuous operation for 13 months before the commencement of this study. The

variables were subjected to joint variance analysis and significance testing (Tukey 5%), and statistical analysis was performed using the InfoStat software carried out by the Advanced Morphophysiological Studies Center at UEMASUL.

Results and discussions

Zootechnical performance is closely linked to effective management practices, fish health, and water quality (Sandoval-Vargas *et al.*, 2020; Zaki *et al.*, 2023). Monitoring and evaluating water quality in suspended tank fish farming operations have a substantial impact on business profitability. The values of water quality variables must fall within the limits stipulated by CONAMA Resolution No. 357 (National Council for the Environment, 2005), as well as align with recommendations from the specialized literature.

Table 1 - Relationship of water quality standards evaluated in tank water and biological filter water, with reference values for parameters according to the limits established by CONAMA, Resolution No. 357/2005 (National Council for the Environment, 2005).

PARAMETER	Tank water	Filter water	VPM*	Units
pH	5.23 a	6.34 b	5.0-9.0	-
Temperature	27.1 a	26.3 b	30	°C
Dissolved Oxygen	5.21 a	7.43 b	>3.0	Mg/L
Total Hardness	20.8 a	15.0 b	≤ 500	ppm
Turbidity	44.33 a	10.33 b	≤ 100	U.N.T
Nitrate	22.14 a	11.04 b	10.0	Mg/L N
Nitrite	0.50 a	0.30 b	1.0	Mg/L N
Ammonia Nitrogen	4.85 a	3.64 b	13.3	Mg/L N
Alkalinity as OH ⁻	0.0	0.0	N C	Mg/L CaCO ₃
Alkalinity as CO ³⁻	0.0	0.0	N C	Mg/L CaCO ₃
Alkalinity as HCO ³⁻	0.0	0.0	N C	Mg/L CaCO ₃
Total Alkalinity	0.0	0.0	N C	Mg/L CaCO ₃
Free Residual Chlorine	0.75 a	0.25 b	≤ 5.0	Mg/L
Chlorides (Cl ⁻)	48.98 a	36.98 b	≤ 250	Cl
Conductivity	3.613 a	1.614 b	N C	μS/cm
Total Phosphorus	6.50 a	5.71 b	0.05	Mg/L P
Total Dissolved Solids	1.8 a	1.8 a	≤ 500.0	PPM
NaCL	0.01 a	0.01 a	N C	%
Manganese	0.0	0.0	0.1	Mg/L Mg
Total Chromium	0.0	0.0	0.05	Mg/L Cr
Zinc	0.0	0.0	≤ 5.0	Mg/L Zn
Orthophosphate	29.88 a	29.88 a	N C	Mg/L P ₂ O ₅
Iron	0.52 a	0.21 b	0.05	Mg/L Fe
Aluminum	0.0	0.0	0.20	Mg/L Al
Sulfide	0.05 a	0.05 a	0.30	Mg/L S

Means followed by different letters differ from each other (P<0.05), according to Tukey's test. *MCL: Maximum Contaminant Level - According to Resolution No. 357/ CONAMA of 03/17/2005. **NR: Not Reported (not established) in Resolution No. 357/ CONAMA of 03/17/2005. Source: Jéssica Antonia Cardoso Mendes (2024).

In fish farming, ponds harbor a highly diverse biotic community, encompassing primary producers, secondary producers, and decomposing microorganisms. However, the

species thriving in these environments crucially rely on water quality, as indicated by physical, chemical, and biological variables (Piscicultura, 2020). Management practices can induce artificial eutrophication, setting off a chain reaction of causes and effects, characterized by system destabilization (Zhang *et al.*, 2020; Mavraganis *et al.*, 2020). This phenomenon is exacerbated as stocking densities (individuals/m³) increase, leading to a rise in the amount of food provided to the animals, and thereby contributing to water quality deterioration.

The pH measurements revealed relative acidity in both the cultivation tank and the biological filter, ranging between 5.23 and 6.34, respectively, slightly below acceptable limits. Optimal pH values for aquaculture typically fall between 7.0 and 8.3; however, working with values between 6.5 and 9.0 is deemed acceptable (Embrapa, 2022). Extreme acidity (pH 4) or alkalinity (pH 11) levels can lead to fish mortality in ponds (Ndubuisi *et al.*, 2015).

Rebouças (2015) reevaluated the ideal pH range and the tolerance of Nile tilapia (*O. niloticus*) juveniles to elevated water acidity under eutrophic cultivation conditions. The authors found that gradual acidification of water up to pH 4 benefits the body growth of the fish. Overall, the assessment of all results in this study suggests that the pH range for *O. niloticus* cultivation spans from pH 4 to 8.

Temperature evaluations indicated that temperatures within the normal range for the proper development of tilapia were observed. It is well-documented that tilapia exhibit better development at water temperatures between 26°C and 30°C (Azaza *et al.*, 2008), which aligns with the temperature range recorded in both the cultivation tank and biological filter. This temperature range directly influences fish productivity by enhancing their daily feed intake and overall well-being.

Oxygen availability and quality are crucial for fish survival, representing a critical aspect in aquaculture practices. Oxygen variations primarily occur due to the density of phytoplankton populations, aquatic macrophytes, and bacteria, which are directly influenced by factors such as daily light hours, brightness, temperature, water nutrients, and tank depth (Diana *et al.*, 2017; Boyd *et al.*, 2018). In the assessment of oxygen levels, it was observed that dissolved oxygen levels in both the cultivation tank and the biological filter were suitable for fish development, remaining within the recommended range for tilapia species (*O. niloticus*), as suggested by Gomes *et al.* (2010) and Mendonça *et al.*, (2012). According to Gelson Hein (2006), the ideal dissolved oxygen level for optimal fish development is above 5 mg/L.

An ideal parameter for detecting pollutant sources is electrical conductivity, providing essential information about the metabolism of the aquatic environment. When the level is high, it indicates a high degree of decomposition, a factor that causes stress for the fish (Makori *et al.*, 2017; Hlordzi *et al.*, 2020). In this study, the biological filter proved effective in treating fish water, reducing conductivity by 1999 $\mu\text{S}/\text{cm}$, and thereby decreasing salt levels and improving water quality and fish well-being.

According to Conama Resolution No. 357/05, there is no established limit for this parameter in aquaculture; however, electrical conductivity is known to be an important factor for the survival of aquatic organisms. Boyd and Tucker (1998) suggest that specific conductivity should be below 1000 $\mu\text{S}/\text{cm}$ for acceptable water quality regarding concentrations of dissolved inorganic substances. In a study conducted by Mercante *et al.* (2007), electrical conductivity consistently remained above 79 $\mu\text{S}/\text{cm}$. Based on the reference values observed by these authors, this variable exceeded acceptable limits, which may indicate a high presence of decomposing organic matter.

Another critical parameter in the metabolism of aquatic ecosystems is nitrogen, a crucial element that requires monitoring as it can act as a limiting factor for primary production in ecosystems (Maberly *et al.*, 2020; Mason *et al.*, 2022). Under certain conditions, nitrogen can quickly become a limiting factor, reaching toxic levels that affect fish survival and growth (Xu *et al.*, 2021; Vaage and Myrick, 2021). Ammonia, nitrate, and nitrite, besides causing stress to fish, can induce histological and biochemical alterations, damage to gills, and a decrease in oxygen transport capacity in the blood, as well as affecting fitness (i.e., organism fitness in terms of growth and swimming) (Araujo *et al.*, 2021), and leading to fin destruction, potentially resulting in fish mortality (Nascimento, 2018). Maintaining low levels of ammonia is essential in aquaculture.

Among the nitrogenous compounds evaluated in this study, ammonia is one of the most concerning pollutants in natural aquatic environments and in intensive aquaculture (Nagaraju *et al.*, 2023). Ammonia is the primary excretion product of fish, and in the environment, it is found as total ammoniacal nitrogen (TAN) ($\text{NH}_3\text{-N}$), which can freely cross the cell membrane and is therefore considered potentially toxic (Mehta, 2017). Nitrite is naturally found in organisms and is also produced by the oxidation of ammonium ions through the nitrification process (Ha *et al.*, 2019). Nitrate, while less directly toxic, can be converted to nitrite in endogenous processes, leading to the formation of methemoglobin and subsequent loss of oxygen transport capacity in the blood (Gomez Isaza *et al.*, 2021).

In the evaluations of ammoniacal nitrogen and nitrite levels in both tanks, there was no significant difference ($P < 0.05$), meeting all treatment requirements according to

Conama Resolution No. 430 of May 13, 2011 (BRASIL, 2011). The nitrate parameter in the tank water analysis demonstrated the effectiveness of the biological filters, rendering the water favorable for fish growth and development, in compliance with Conama resolutions no. 357/2005 and 430/2011.

Non-ionized ammonia was not estimated; however, according to Kubitzka (2003), concentrations of non-ionized ammonia above 0.02 mg/L are sufficient to induce chronic toxicity, leading to decreased fish growth and disease tolerance. If the concentration reaches 0.02 mg/L, the application of agricultural lime is suggested as a water management proposal to improve pond water quality, aiming to enhance water buffering capacity and reduce daily pH fluctuations.

An essential point to highlight is the synergistic or antagonistic effect between increased temperature on fish physiology. A study by Gomez Isaka *et al.* (2021), exposed Australian fish of the species Silver Perch (*Bidyanus bidyanus*), to nitrate at different concentrations and temperatures: 28°C (study site temperature) and 32°C (elevated temperature) for 21 weeks. The authors reported that exposure to high nitrate reduced the oxygen transport capacity in the blood due to increased methemoglobin at both temperatures. On the other hand, exposure to higher temperatures (32°C) increased the gill surface area and ventricular thickness, regardless of nitrate concentration. The authors concluded that this plasticity of the cardiorespiratory system protects against simultaneous exposure to nitrate and high temperatures.

Regarding water turbidity (a measure of the difficulty of a light beam passing through a certain amount of water), several factors interfere with turbidity measurements, such as water color and carbon particles, due to their light-absorbing properties. Therefore, samples should be analyzed shortly after collection, as turbidity may change if the sample is stored for some time.

In the turbidity assessment, both tanks exhibited favorable levels for good development of the tilapia. However, the fish tank showed higher turbidity ($P < 0.05$), likely attributed to the input of organic matter from feeding, fish feces, phytoplankton and zooplankton communities, and inorganic debris. Observing the averages, it was evident that the biological filter displayed a better turbidity parameter ($P < 0.05$), demonstrating the efficiency of the filters and meeting Brazilian Conama standards for fish farming in Brazil. It is essential to highlight that pollutant toxicity can vary according to concentration, water quality conditions, exposure period, and the sensitivity of each species (Kim and Kang, 2016; Kubitzka, 2019).

The alkalinity levels in OH⁻, CO₃⁻, HCO₃⁻, and total remained at 0.00 mg/L, indicating that they were not detected in the analysis. It is important to note that the total alkalinity did not exceed the minimum acceptable limit of 20 mg/L. This value may be considered low for maintaining the buffering effect, which increases with higher alkalinity levels. Additionally, free residual chlorine, chloride, manganese, and iron were evaluated. Chlorine, a strong oxidizing mineral, can be lethal to most fish at levels between 0.1-0.3 ppm. It is preferable to maintain levels below 0.001 to 0.003 ppm, as health problems may arise in aquatic systems. Since chlorine is an excellent disinfectant, its presence can lead to the killing of many beneficial bacterial strains in water or biological filter systems. Super exposure to chlorine levels above 0.3 ppm in fish can also cause breathing difficulties, suffocation, or, in some cases, death.

In the evaluation of residual chlorine and chloride (Cl⁻), both the cultivation tank and the biological filter exhibited favorable levels for the good development of tilapia. However, the biological filter proved efficient in reducing chlorine concentrations in the water (P<0.05).

Phosphorus is an essential nutrient for the growth of organisms and can limit the primary productivity of water bodies. In fish farming, 66% of the phosphorus from feeding goes to sediment, 23% is incorporated by the fish, and 11% dissolves in the water. Although food is more critical than water in meeting the phosphorus needs of fish, approximately 90% of the phosphorus from this source is allocated to the structure of support tissues. However, phosphorus supplementation in diets is essential due to the low assimilation capacity fish have from the aquatic environment.

Nutrient enrichment, such as phosphorus, in fish farming tanks, is common, mainly due to the entry of compounds from feeding, as feeds contain this element. However, the inappropriate use of this nutrient, combined with various other biotic and abiotic factors, can lead to environmental and financial losses. In this study, the biological filter was effective in reducing total phosphorus (P<0.05), but the observed concentrations exceeded the acceptable upper limits of up to 0.030 mg/L. Concentrations of reactive soluble phosphorus or orthophosphate, the biologically assimilable element, showed no statistical difference (P<0.05), with a concentration of 28.88 mg/L of P₂O₅ in both tanks. This indicates high levels of organic and inorganic matter in the system. There are no reports in the literature about lethal levels of orthophosphate for fish, only data on lethal levels for other nutrient parameters in the aquatic environment, such as ammonia and nitrite.

Although elevated phosphorus concentrations may not directly affect fish, their cumulative effects are closely linked to the excessive growth of phytoplankton

communities and the potential proliferation of Cyanobacteria. Orthophosphate is particularly significant as it is the primary form assimilated by aquatic plants (Rezania *et al.*, 2021; Dillon and Molot, 2024).

According to Cagol *et al.* (2016), who evaluated lethal concentrations and safety levels of phosphorus for Nile tilapia (*Oreochromis niloticus*), concentrations ranging from 0 to 400 mg/L were not lethal. However, at the highest concentration (10,000 mg/L), 100% mortality was observed within 1 hour. Concentrations of 5,000 mg/L and 1,000 mg/L caused 60% mortality of fish within 24 hours and 100% within 48 hours. Therefore, a safe level for the exposure of juvenile tilapia is less than 100 mg/L of phosphorus, representing 10% of the lethal concentration that caused 60% mortality within 24 hours.

In both types of cultivation systems, employing biofilters and water renewal systems (RAS) serves the purpose of enhancing water quality to sustain suitable solid levels for production within a water recirculation framework. This approach targets the enhancement of cultivation conditions concerning the presence of suspended solids in the fish tank, with recommended concentrations of suspended solids up to 500 mg/L, although reports indicate levels of up to 1,000 mg/L (Mohammadi *et al.*, 2021).

Conclusion

According to Resolution No. 357, dated March 17, 2005, from the National Environment Council - CONAMA, the analyzed water does not meet the parameters required by the legislation for the conducted analyses. However, the biological filter demonstrated the expected benefits by improving the water quality of the commercial pond. The water plants, Mururu (*Eichornia crassipes*) and Taboa (*Typha domingensis*), along with the media area, proved to be efficient in removing nitrogenous metabolites from the pond. Further adjustments are still necessary for the consolidation of the system, but the implementation of the biological filter could enhance water quality in a water recirculation system in commercial fish farming.

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