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Carbon content in sediment from tambaqui fry ponds in fish farming in the Western Amazon

Teores de carbono em sedimento de viveiros de alevinagem de tambaqui em piscicultura na Amazônia Ocidental

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A B S T R A C T

Fish farming in the state of Rondônia is characterized by adopting, in the great majority, the nurseries excavated without geomembrane. The effect of high stocking densities and leftover rations with a high nutrient content are decisive factors for the deterioration of the quality of the cultivation environment, as well as factors that trigger diseases that disperse rapidly in the environment due to water eutrophication. The objective was the chemical analysis of the levels of organic carbon and organic matter in the sediment of excavated ponds used in the creation of tambaqui fry (*Colossoma macropomum*). The study was carried out at the Vale do Rio Machado fish farm, located on line 20, BR sector of the rural area of the municipality of Presidente Médici, Rondônia. The sediment samples were collected with the aid of a simple collector in six nursery of fingerlings (V01, V02, V03, V04, V12 and V13) considering a depth of 0 to 20 cm, at three points inside the nursery (triplicate): close at the water inlet, in the middle of the pond and close to the water outlet, with the exception of the ponds 01 and 02, since they are concentrated in the same point the entrance and exit, as well as the entrance and the middle of the pond, respectively. The dynamics of organic carbon and organic matter present in the sediment is directly linked to the flow of water in the nurseries.

R E S U M O

A piscicultura no estado de Rondônia é caracterizada por adotar, em sua grande maioria, os viveiros escavados sem geomembrana. O efeito de elevadas densidades de resíduos e sobras de rações com nutrientes são fatores decisivos para a deterioração da qualidade do ambiente de cultivo, bem como fatores desencadeadores de doenças que se dispersam rapidamente no meio devido à eutrofização da água. Objetivou-se analisar os teores de carbono orgânico e matéria orgânica do sedimento de viveiros escavados utilizados na criação de alevinos de tambaqui (*Colossoma macropomum*). O estudo foi realizado na piscicultura Vale do Rio Machado, localizada na linha 20, setor BR da área rural do município de Presidente Médici, Rondônia. As amostras de sedimento foram coletadas com auxílio de um coletor simples em seis viveiros de alevinagem (V01, V02, V03, V04, V12 e V13) considerando uma profundidade de 0 a 20 cm, em três pontos dentro do viveiro (triplicata): próximos à entrada de água, no meio do viveiro e próximo à saída de água, com exceção dos viveiros 01 e 02, uma vez que se concentram em mesmo ponto a entrada e saída, bem como a entrada e o meio do viveiro, respectivamente. A dinâmica do carbono orgânico no sedimento está diretamente interligada ao fluxo de água existente nos viveiros

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Introduction

In recent decades, aquaculture has emerged as a competitive and sustainable activity in the production of healthy food, making significant contributions to employment generation and income, as well as reducing poverty and hunger in various parts of the world. The economic and social impacts generated by aquaculture activities have been so extensive that this experience has been termed the "blue revolution," in reference to the "green revolution," which brought about significant transformations in agricultural activities and people's lifestyles starting in the 1950s (Siqueira, 2017).

According to data presented in the 2022 edition of "The State of the World Fisheries and Aquaculture – Towards Blue Transformation" (FAO, 2022), despite the COVID-19 pandemic, global aquaculture production grew by 5.7%, reaching approximately 122.6 million tons in 2020. Of this amount, about 87.5 million tons were aquatic animals, with an estimated value of $281.5 billion. In 2022, Brazil had an average production of 860,344 tons of farmed fish, an increase of 2.3% compared to 2021 (Peixe BR, 2023).

According to information published in the 2023 Annual Report by Peixe BR, fish production in Brazil reached 267,060 tons, with 31.04% corresponding to the production of native fish (Peixe BR, 2023). The Northern Region stands out with 143,500 tons of this production, with the state of Rondônia being the largest producer of native fish in Brazil, totaling 57,200 tons of native fish produced in 2022 (Peixe BR, 2023). The tambaqui (Colossoma macropomum CUVIER, 1818) is one of the most cultivated fish, accounting for about 88% of the fish farmed in Rondônia in 2022 (IBGE, 2023).

Given these insights, one of the existing concerns is the sediments produced during the production cycle of tambaqui fingerlings. These sediments can be defined as mineral particles (between 95% to 98%) and organic particles (between 2% to 5%) found at the bottom of ponds. While they are an important component of the aquatic ecosystem, providing substrate for a diversity of organisms, they also function as reservoirs for various low-solubility contaminants. They play a significant role in the assimilation, transport, and deposition of organic and mineral matter, and can constitute sources of secondary contamination in the water column. However, sediment deposition should be prevented through better aeration techniques and its use in the pond's maintenance after drying between production cycles, as it can be reapplied in erosion-prone areas (Boyd, 2012; Brigante et al., 2003).

The organic carbon and organic matter content in the sediments of excavated ponds result from various factors, including the source water quality, tank management practices (liming, fertilization, cleaning), species characteristics, and production management, especially regarding feed supply and quality (Barbosa et al., 2000).

The dynamic interaction between organic matter and nutrient availability in pond sediments, originating from feed provision during tambaqui cultivation, is considered a critical aspect for management. The decomposition of organic matter affects the availability of dissolved oxygen (DO) and the redox potential at the sediment-water interface, reducing nutrient exchange from the sediment to the water column (De Queiroz & Boeira, 2006).

In this context, the objective of this research was to evaluate the levels of carbon and organic matter in the sediment of fingerling ponds in a fish farm in the municipality of Presidente Médici, Rondônia.

Development

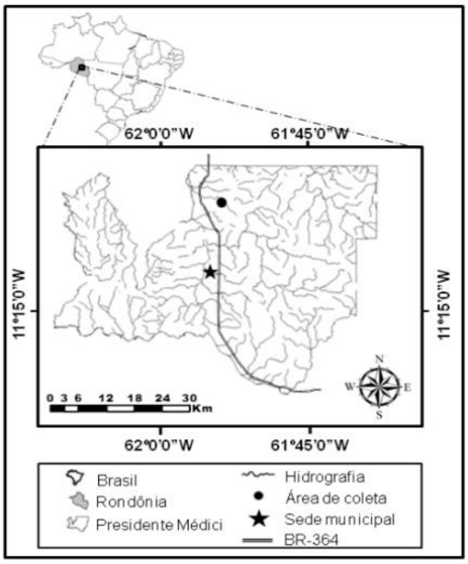
Study Area

The chosen study area is located in the municipality of Presidente Médici, Rondônia (Figure 1), situated in the Central Region of the state, with an approximate population of 19,327 inhabitants, according to the 2022 census. Data show that the largest economic activity contributing to the municipality's gross domestic product (GDP) is agriculture (IBGE, 2022).

This research was conducted on a rural property, Piscicultura Vale do Rio Machado, where the climate is classified as Aw, humid or subhumid, according to Köppen, with an average annual air temperature around 25.8°C, a maximum temperature between 30°C and 34°C, a minimum between 17°C and 23°C, and an average annual rainfall of 1,757 mm (Climate-Data, 2024).

The fish farm has 13 excavated tanks (ponds) varying between 20 to 100 m², with a maximum depth of 1.50 m. This fish farm is intended for the production of tambaqui fingerlings (Colossoma macropomum CUVIER, 1818) for commercialization. The ponds are supplied with water from a spring located on a neighboring property upstream of the fish farm, passing through two supply reservoirs without fish cultivation, and subsequently distributed to the ponds with a continuous flow water supply system interconnected in a cascade. The research was conducted only in the fingerling ponds (01, 02, 03, 04, 12, 13), excluding the ponds containing the broodstock (Figure 2).

Figure 1.
Location of the data collection area.



Source: Freitas et al. (2015).

Sediment Collection in Fingerling Ponds

The study was conducted from August 2015 to June 2016, with five bi-monthly sampling campaigns, always carried out in the morning. Sediment samples were collected from ponds (01, 02, 03, 04, 12, 13), with tanks beyond pond 13 belonging to another farm and not used for fish farming activities (Figure 2).

A simple collector was used for sediment sampling. The collector consisted of a transparent polyvinyl chloride (PVC) tube, with a diameter of 5 cm and approximately 2.0 m in length, allowing relatively undisturbed samples to be obtained (De Queiroz et al., 2004a).

Sediment samples were collected from six fingerling ponds: 01, 02, 03, 04, 12, and 13 (Figure 2). Samples were taken at a depth of 0 to 20 cm (due to the likely surface concentration of nutrients) and at three points within the pond (triplicate): near the water inlet, in the middle of the pond, and near the water outlet. Exceptions were ponds 01 and 02, where the inlet and outlet are at the same point, and the inlet and middle of the pond, respectively, as recommended by Brandão et al. (2011) for selecting sediment sampling points for organic matter analysis. After homogenization, samples were placed in labeled plastic bags and transported to the Laboratory of Physical-Chemical and Microbiological Analyses at the Presidente Médici Campus of UNIR, according to the methodology of Ribeiro et al. (2005) and Da Silva & Da Silva (2009).

Figure 2.
Vale do Rio Machado’s fish farming.

Source: Adapted from Google Earth (accessed on January 21, 2024).

Laboratory Analyses

Samples were dried and sieved through a 2 mm mesh. Organic carbon (OC) quantification was performed by oxidizing organic matter using potassium dichromate in sulfuric medium, according to the methodology described in Claessen (1997) and Da Silva & Da Silva (2009).

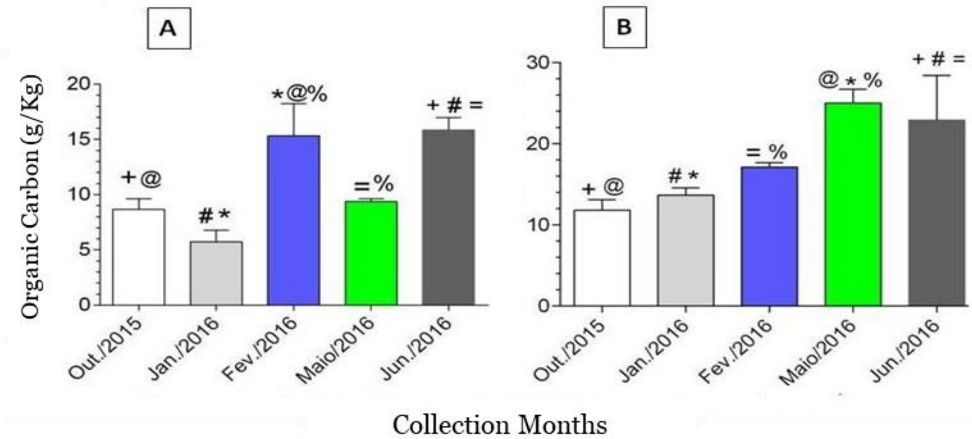
Statistical Analyses

Data were subjected to variance analysis using the Shapiro-Wilk test through the statistical program OriginPro 8. Analyses of variance (ANOVA) and Tukey's test ($p = 0.05$) were performed. Graphs were created using GraphPad Prism (6.0).

Results

Organic carbon (OC) values for ponds 01, 02, 03, 04, 12, and 13 at different sampling points, analyzed by ANOVA, showed significant differences between the months collected. For pond 01 at the inlet/outlet point, the months of October 2015, January 2016, and May 2016 showed no differences among themselves, as did February 2016 and June 2016 (Figure 3A). For the middle of the pond, the months of October 2015, January 2016, and February 2016 showed no differences, nor did May 2016 and June 2016 (Figure 3B).

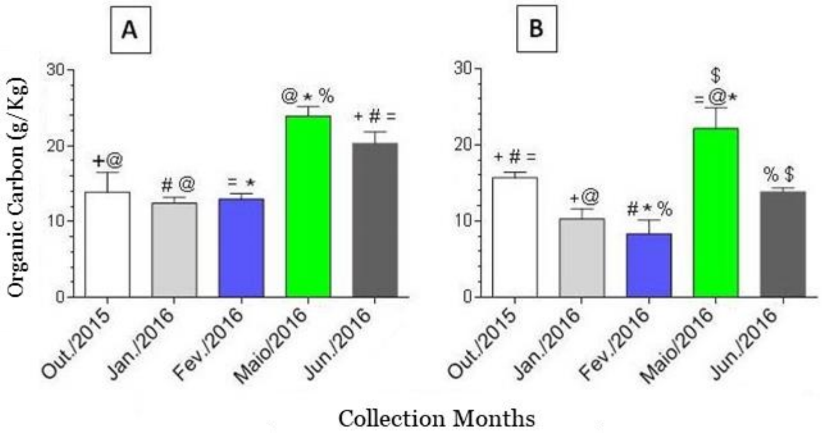
Figure 3.
Organic carbon values for pond 01. A – Inlet/Outlet. B – Middle.



Comparison of values obtained in the sampling months was conducted through ANOVA followed by Tukey's test ($p < 0.05$), with columns followed by the same symbols showing significant differences

For pond 02 at the inlet/middle point, the months of October 2015 and February 2016; January 2016 and February 2016 showed no differences among themselves, nor did May 2016 and June 2016 (Figure 4A). For the outlet point, the months that showed no differences were October 2015 and June 2016; January 2016 and February 2016; January 2016 and June 2016 (Figure 4B).

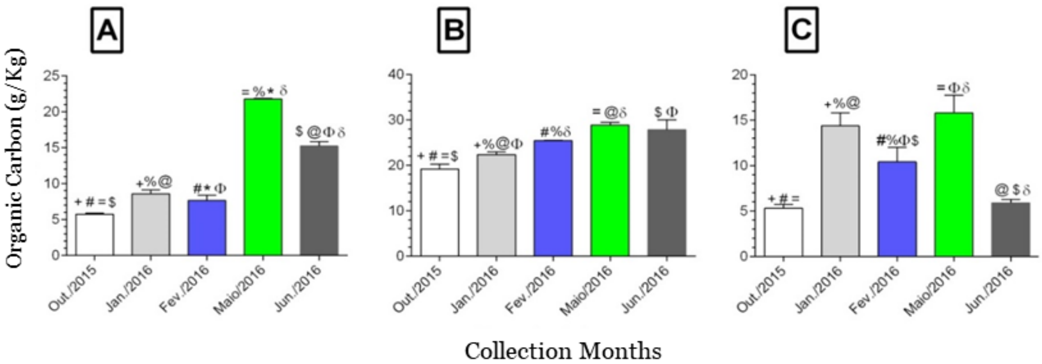
Figure 4.
Organic carbon values for pond 02. A – Inlet/Middle. B – Outlet.



Comparison of values obtained in the sampling months was conducted through ANOVA followed by Tukey's test ($p < 0.05$), with columns followed by the same symbols showing significant differences

In pond 03 at the inlet point, only January 2016 and February 2016 (Figure 5A) showed no differences among themselves. For the middle of the pond, only February 2016 and June 2016; May 2016 and June 2016 (Figure 5B) showed no differences. At the outlet point, the months with no differences were October 2015 and June 2016; January 2016 and May 2016; February 2016 and June 2016 (Figure 5C).

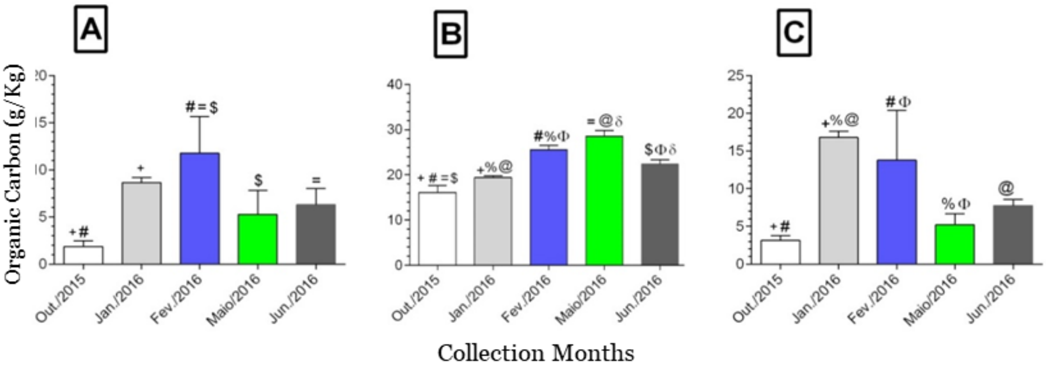
Figure 5.
Organic carbon values for pond 03. A – Inlet. B – Middle. C – Outlet.



Comparison of values obtained in the sampling months was conducted through ANOVA followed by Tukey's test ($p < 0.05$), with columns followed by the same symbols showing significant differences

In pond 04 at the inlet point, the months of October 2015, May 2016, and June 2016; January 2016 and February 2016; January 2016, May 2016, and June 2016 (Figure 6A) showed no differences among themselves. For the middle of the pond, the months of January 2016 and June 2016; February 2016 and May 2016 (Figure 6B) showed no differences. At the outlet point, the months with no differences were October 2015, May 2016, and June 2016; January 2016 and February 2016; February 2016 and June 2016 (Figure 6C).

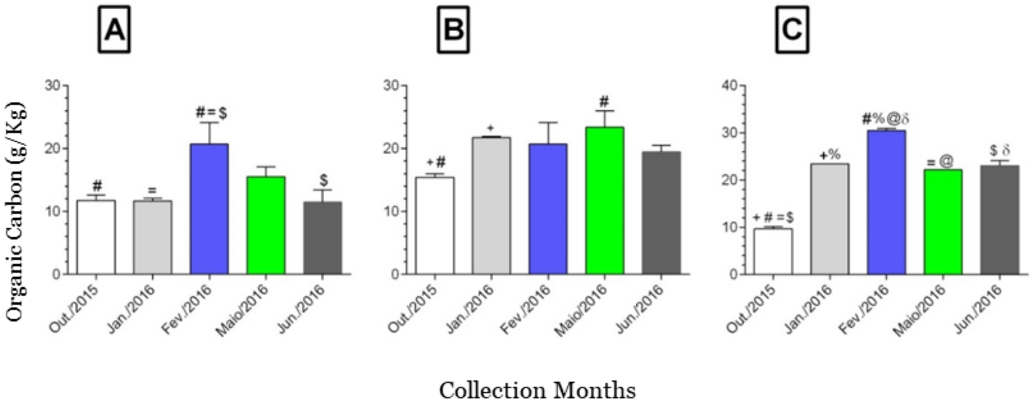
Figure 6.
Organic carbon values for pond 04. A – Inlet. B – Middle. C – Outlet.



Comparison of values obtained in the sampling months was conducted through ANOVA followed by Tukey's test ($p < 0.05$), with columns followed by the same symbols showing significant differences

For pond 12 at the inlet point, the months of October 2015 and February 2016; January 2016 and February 2016 showed differences between the observed months (Figure 7A). For the middle of the pond, the months of October 2015 and January 2016, as well as October 2015 and May 2016 (Figure 7B), showed differences. At the outlet point, October 2015 showed differences between the months of January 2016 – February 2016 – May 2016 – June 2016; January 2016 and February 2016; as well as February 2016 and May 2016 – June 2016 (Figure 7C).

Figure 7.
Organic carbon values for pond 12. A – Inlet. B – Middle. C – Outlet.

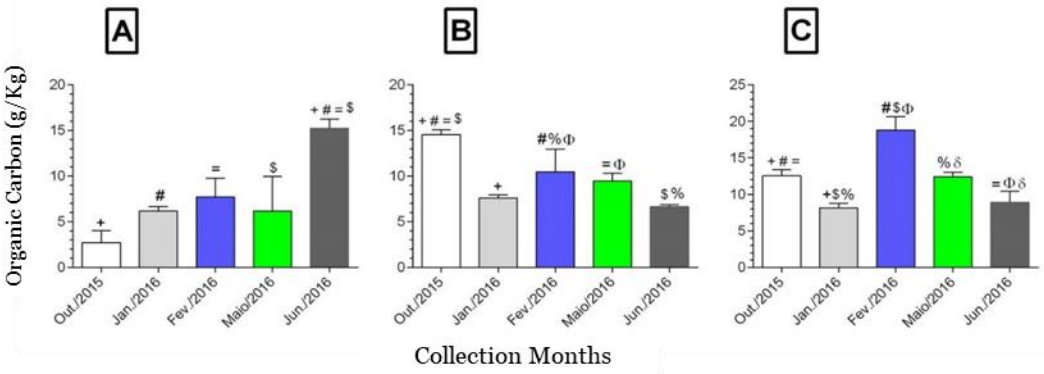


The comparison between the values obtained in the sampling months was performed using analysis of variance (ANOVA) followed by Tukey's test ($p < 0.05$); columns followed by the same symbols indicate significant differences

The results obtained in pond 13 at the inlet point show significant differences between October 2015, January 2016, February 2016, May 2016, and June 2016 (Figure 8A). For the middle of the pond, October 2015 showed differences compared to January 2016, February 2016, May 2016, and June 2016; as well as February 2016 compared to May 2016 and June 2016, respectively (Figure 8B). However, at the outlet point, October 2015 showed differences with January 2016, February 2016, and June 2016; as well as January 2016 with February 2016 and May 2016; and February 2016 with June 2016; and May 2016 with June 2016 (Figure 8C).

Figure 8.

Organic carbon values in pond 13. A – Inlet. B – Middle. C – Outlet.

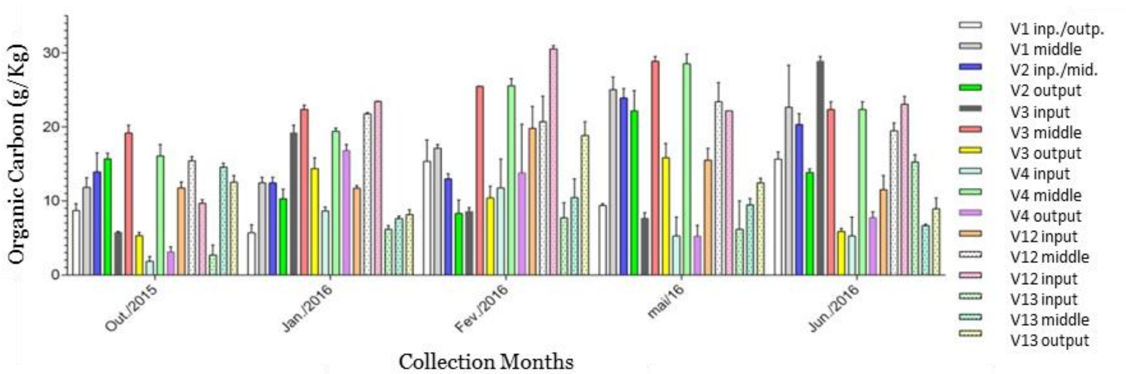


The comparison between the values obtained in the sampling months was performed using analysis of variance (ANOVA) followed by Tukey's test ($p < 0.05$); columns followed by the same symbols indicate significant differences

Figure 9 shows the variation of organic carbon in the ponds throughout the experiment. The results allowed us to verify that there was no consistent temporal or spatial pattern for the concentration of organic carbon in the collected sediments. The lowest concentration was obtained in pond 13/inlet in October 2016 with a value of 4.83 g/kg, and the highest value was obtained in pond 12/outlet in February 2016.

Figure 9.

Variation in the average organic carbon content of the sediment.



Discussion

In aquaculture, the sediment layers in ponds are as crucial as water quality, as the substances present in the sediments are in dissolution equilibrium with the water layer, allowing for the exchange of these substances between these layers (De Souza et al., 2021). Ribeiro et al. (2012) note that it is common for old aquaculture ponds to accumulate organic matter due to multiple cultivation cycles, resulting in higher soil fertility due to fish feeding, where uneaten feed and increased excrement accumulate over the extended duration of fish presence.

In the studied aquaculture farm (Piscicultura Vale do Rio Machado), the owner reported not drying the tanks to remove excess bottom sediments, which is one of the Good Management Practices (GMP) recommended in aquaculture by Boyd and Queiroz (2004). However, at the end of the fry sale, the farmer's management practices include liming and fertilization, which are also performed as needed during cultivation.

The liming method adopted in this aquaculture farm involves the direct application of agricultural lime on the pond's water surface in February (two to three weeks before the fry are introduced). The study by De Queiroz et al. (2004b) demonstrated that the increase in sediment pH was completed within one to two months after the application of agricultural lime, and it did not affect sediment layers below 8 cm.

Based on the organic carbon results of the studied sediment, there is variability and/or instability (Figure 9) during the collected months (cultivation cycle), indicating that the application of agricultural lime did not influence these variables. Additionally, the "inlet," "middle," and "outlet" positions (sampling points) of the pond water did not exert any influence on the sediment accumulation.

All fry ponds showed different behavior throughout the sampling period and in the sampling positions regarding the sediment's organic carbon content, a similar result to that obtained by Barbora et al. (2015). According to Ribeiro et al. (2005), the feed being thrown daily at the same spot in the pond does not only settle in the spot it is thrown but disperses in the water due to wind, significantly increasing the variability of organic matter and organic carbon in the aquaculture pond sediment, as these compounds result from the excessive nutrient load (feces, organic fertilization, food remains, etc.) present in the cultivation water.

However, residual particles suspended in the water or adhered to the pond sediment mainly originate from the organic carbon present in the sediment, which is significantly favored by the increased organic load in the environment and the management practices employed in the fry tanks (liming, drying, and fertilization). Therefore, monitoring the sediment's chemical parameters is essential for controlling eutrophication in dug ponds with excess nutrients (Rahman et al., 2008).

According to Vinatea et al. (2006), pH values are inversely proportional to organic carbon values. This relationship can be explained by the fact that during the decomposition of organic compounds, there is a high demand for O2 (progressive depletion of O2). Thus, the higher the organic carbon concentration in the sediment, the greater the O2 consumption to decompose this nutrient load, and the lower the pH value of the environment.

Another study that mentions organic carbon levels is by Barbosa et al. (2015), which, when studying sediment in an Amazonian pintado production system, demonstrated that all analyzed ponds showed no linear behavioral difference in organic carbon throughout the sampling period.

The results suggest that the dynamics of organic carbon may be related to water flow (current), which promotes the recirculation of sediment at the pond bottom, preventing significant accumulation. According to Boyd (2012), water flow at the pond bottom is highly relevant in decomposing nutrients present in the sediment.

Finally, to maintain the desired quality parameters of aquaculture ponds and a suitable environment for fry growth, it is recommended as a GMP that sediments be regularly removed (Haque et al., 2013). Otherwise, managing the removed sediments is a concern, as disposing of them in inappropriate locations is an environmental threat and a waste of nutrients (Muendo et al., 2014).

Conclusions

The different sampling points did not influence the results related to sediment accumulation in the fry ponds.

The dynamics of organic carbon and organic matter present in the sediment are linked to the existing water flow in the ponds, which promotes sediment recirculation at the bottom, preventing organic load accumulation.

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REFERENCES

Barbosa, D. S., Oliveira, M. D., Nascimento, F. L., & Silva, E. (2000). Avaliação da qualidade da água na piscicultura em tanques-rede, Pantanal, MS. *Simpósio Sobre Recursos Naturais e Sócio-Econômicos Do Pantanal, Corumbá, MS. Anais. Corumbá, 14p*.

Barbosa, P. T., Pereira, G., Porto, E. P., & Pires, T. (2015). Sistema de Produção de Pintado Amazônico: Caracterização das variáveis físicas e químicas da água e do sedimento. *Enciclopédia Biosfera, 11 (*21), pp. 1736-1748.

Brandão, C., Botelho, M. J. C. & Sato, M. I. Z. (2011) *Guia nacional de coleta e preservação de amostras: água, sedimento, comunidades aquáticas e efluentes líquidos*. São Paulo: CETESB; Brasília: ANA, 2011. 326p

Brigante, J., Espíndola, E. L. G., Povinelli, J., & Nogueira, A. M. D. N. (2003). Caracterização física, química e biológica da água do rio Mogi-Guaçu. In: Espíndola, E. L. G., Brigante, J. *Limnologia fluvial: um estudo no rio Mogi Guaçu*. São Carlos: RiMa, pp. 55-76

Boyd, C. E. (2012). *Bottom soils, sediment, and pond aquaculture*. (1995th edition). Springer Science & Business Media. 367p.

Boyd, C. E., & Queiroz, J. D. (2004). Manejo das condições do sedimento do fundo e da qualidade da água e dos efluentes de viveiros. In: Cyrino, J. E. P., Urbinati, E. C., Fracalossi, D. M., Castagnolli, N. *Tópicos especiais em piscicultura de água doce tropical intensiva. Jaboticabal: Sociedade Brasileira de Aquacultura e Biologia Aquática*, São Paulo: TecArt, pp. 25-43.

Claessen, M. E. C. (1997). Manual de métodos de análise de solo. *Embrapa Solos-Documentos (INFOTECA-E).*

Climate-data.org. *Clima de Presidente Médici*. https://pt.climate-data.org/740mérica-do-sul/brasil/rondonia/presidente-medici-31796/.

Da Silva, F. C., & Da Silva, F. C. (2009). *Manual de análises químicas de solos, plantas e fertilizantes*. (2ª ed.). Brasília, DF: Embrapa Informação Tecnológica; Rio de Janeiro: Embrapa Solos, 2009. 627p. https://www.infoteca.cnptia.embrapa.br/infoteca/handle/doc/330496

De Queiroz, J. F., Nicolella, G., Wood, C. W., & Boyd, C. E. (2004). Métodos de calagem, acidez da água e do sedimento do fundo de viveiros de piscicultura. *Scientia Agricola*, *61 (*5), pp. 469-475. a

De Queiroz, J. F., Boeira, R. C., & Silveira, M. P. (2004). *Coleta e preparação de amostras de sedimentos de viveiros de aquicultura*. Embrapa Meio Ambiente. Comunicado Técnico. 17. Jaguariúna – SP, 5p. b

De Queiroz, J. F., & Boeira, R. C. (2006). *Recomendações práticas para o manejo de sedimentos do fundo dos viveiros de aquicultura*. Embrapa Meio Ambiente. Comunicado Técnico. 37. Jaguariúna – SP, 6p

De Souza, R. A. L., Takata, R., de Souza, A. D. S. L., da Silva Júnior, M. L., & da Silva, F. N. L. (2021). Caracterização de sedimentos em viveiros de piscicultura na Amazônia Oriental, Brasil. *Research, Society and Development*, *10* (1), pp. 1-10 e41710111815-e41710111815.

FAO, Food and Agriculture Organization of the United Nations. (2022). *The State of World Fisheries and Aquaculture 2022*. Towards Blue Transformation. Rome. 266p. https://doi.org/10.4060/cc0461en

Freitas, C. O., Oliveira, W. I., Silva, E. E., LEITE, E. S., & de Souza, R. H. B. (2021). Estudo de viabilidade econômica para o cultivo do peixe ornamental *Betta splendens* na região Central de Rondônia. In *Anais do Congresso Brasileiro de Custos-ABC*. https://anaiscbc.emnuvens.com.br/anais/article/view/4880

IBGE, Instituto Brasileiro de Geografia e Estatística. (2022). Censo Demográfico. Rio de Janeiro. https://www.ibge.gov.br/cidades-e-estados/ro/presidente-medici.html.

IBGE, Instituto Brasileiro de Geografia e Estatística. (2023). Pesquisa da Pecuária Municipal. https://www.ibge.gov.br/estatisticas/economicas/agricultura-e-pecuaria/9107-producao-da-pecuaria-municipal.html

Haque, M. M.; Monira, M. S.; Salam, M. A.; Shinn, A. P., & Little, D. C. (2013) Use of Pangasius pond sediment for rooftop bag gardening: potential for rural-urban integrated aquaculture-horticulture. *Aquaculture Asia*, 18, pp. 21–23.

Muendo, P. N., Verdegem, M. C., Stoorvogel, J. J., Milstein, A., Gamal, E. N., Duc, P. M., & Verreth, J. A. J. (2014). Sediment accumulation in fish ponds; its potential for agricultural use. *International Journal of Fisheries and Aquatic Studies*, 1 (5), pp. 228-241.

Peixe BR. (2023). *Anuário de Piscicultura Brasileira 2023*. Associação Brasileira da Piscicultura: São Paulo, Brasil. 65p. https://www.peixebr.com.br/anuario/

Rahman, M. M., Jo, Q., Gong, Y. G., Miller, S. A., & Hossain, M. Y. (2008). A comparative study of common carp (*Cyprinus carpio L.*) and calbasu (*Labeo calbasu Hamilton*) on bottom soil resuspension, water quality, nutrient accumulations, food intake and growth of fish in simulated rohu (Labeo rohita Hamilton) ponds. *Aquaculture*, *285*, pp. 78-83.

Ribeiro, P. A. P., Melo, D. C., Costa, L. S., & Teixeira, E. A. (2012). Manejo nutricional e alimentar de peixes de água doce. *Belo Horizonte: Universidade Federal de Minas Gerais*.

Ribeiro, R. P., Sengik, E., Barrero, N. M. L., Ciola, A. L., Moreira, H. L. M., Sussel, F. R., Lupchinski Junior, E., & Benites, C. (2005) Coleta de amostras de sedimentos em viveiros de piscicultura. *Acta Scientiarum. Animal Sciences*, 27 (3), pp. 399-403.

Siqueira, T. D. (2017). Aquicultura: a nova fronteira para aumentar a produção mundial de alimentos de forma sustentável. *Boletim regional urbano e ambiental (IPEA) p. 54.*

Vinatea, L., Malpartida, J. & Andreatta, E. R., (2006). Characterization of pH, organic carbon and redox potential in pond soils of semi-intensive culture of marine shrimp *Litopenaeus vannamei*. *Boletim do Instituto de Pesca Sao Paulo*, 32 (1), pp. 25-30