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Produção de Juvenis de tilápia do Nilo (*Oreochromis niloticus*) em diferentes tecnologias de cultivo: Autotrófico, Simbiótico e Bioflocos

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Larissa Joyce Lopes Nunes

Dissertação apresentada ao Programa de Pós-Graduação em Recursos Pesqueiros e Aquicultura da Universidade Federal Rural de Pernambuco como exigência para obtenção do título de Mestre

Profa. Dra. Juliana Ferreira dos Santos
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"A mente que se abre a uma nova ideia jamais voltará ao seu tamanho original."

Albert Einstein

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Resumo

Com o passar dos anos a aquicultura vem crescendo, e a piscicultura por sua vez se destacando no cenário produtivo. A tilápia do Nilo (*Oreochromis niloticus*), principal espécie produzida no Brasil, é uma das principais no mundo, por apresentar rusticidade e pacote tecnológico para seu cultivo, porém há uma lacuna de conhecimento na produção de juvenis com uso de novas tecnologias. Esse trabalho teve como objetivo avaliar a produção de juvenis de *Oreochromis niloticus*, submetidos a diferentes tecnologias de cultivo: autotrófico, simbiótico e bioflocos. O experimento foi realizado durante 40 dias em triplicata com peixes com peso inicial de 3,59±0,32g em densidade inicial de 500 peixes/m^3, alimentados com ração comercial (Nutripiscis Starter, 46% de PB e 9% de EE). Antes da estocagem dos peixes, as unidades experimentais foram preparadas durante 30 dias com as fertilizações para cada tratamentos: inorgânica (nitrato de potássio e superfostato simples- autotrófico) e orgânica (açúcar demerara - BFT, farelo de arroz fermentado com probiótico - Simbiótico). A tecnologia de bioflocos e simbiótico não apresentaram diferenças significativas ($p>0,05$), e exibiram os melhores resultados para a volume da biomassa planctônica (fito >9mil cels/mL e >10mil cels/mL; zoo >50 org/mL em ambos), produtividade (9,59±0,34 e 10,55±0,35 Kg/m^3), FCA (0,65±0,05 e 0,76±0,10), sobrevivência (88,33±2,89% e 90,00±5,00%), peso final (21,58±1,14g e 22,90±1,28g) em relação ao controle e autotrófico. Além disso, para qualidade de água (NAT - 1,01 ± 0,05 mg/L e 1,03 ± 0,06 mg/L; $N\text{-}NO_2$ - 0,42 ± 0,07 mg/L e 0,64 ± 0,01 mg/L) e pegada hídrica (197,54 ± 2,00 L/kg e 200,16 ± 1,15 L/kg). Entretanto o oxigênio dissolvido foi menor em BFT e simbiótico, quando comprado ao controle. A microbiologia exibiu o simbiótico com maiores valores de UFC para o meio MYP (*Bacillus sp.* $5,50\times10^5$ $\pm3,00\times10^3$ UFC), o bioflocos com a maior contagem padrão (PCA- $8,72\times10^9 \pm 1,00\times10^3$ UFC), enterobactérias (BEM -$4,04\times10^9 \pm 6,10\times10^6$ UFC) e bactérias Gram negativas ($4,67\times10^7 \pm 1,01\times10^5$ UFC), autotrófico e controle, tiveram os menores valores de UFC nas amostras analisadas. Desta forma, podemos concluir que as tecnologias BFT e Simbiótico são promissores para melhorar os resultados de produção zootécnica de juvenis de tilápias do Nilo.

Palavras-chave: fertilização, qualidade de água, índice zootécnico,microbiologia.

Abstract

Over the years, aquaculture has been growing, and fish farming in turn has stood out in the production scenario. Nile tilapia (*Oreochromis niloticus*), the main species Nile tilapia (*Oreochromis niloticus*), the main species produced in Brazil, is one of the main species in the world, due to its rusticity and technological package for its cultivation, however there is a gap in knowledge in the production of juveniles using new technologies. This work aimed to evaluate the production of *Oreochromis niloticus* juveniles, subjected to different cultivation technologies: autotrophic, synbiotic and bioflocs. The experiment was carried out for 40 days in triplicate with fish with an initial weight of 3.59±0.32g at an initial density of 500 fish/m3, fed with commercial feed (Nutripiscis Starter, 46% CP and 9% EE). Before storing the fish, the experimental units were prepared for 30 days with fertilization for each treatment: inorganic (potassium nitrate and simple superphosphate - autotrophic) and organic (demerara sugar - BFT, rice bran fermented with probiotic - Synbiotic). Biofloc and Synbiotic technology showed no significant differences (p>0.05), and exhibited the best results for planktonic biomass volume (phyto >9 thousand cells/mL and >10 thousand cells/mL; zoo >50 org/mL in both), productivity (9.59±0.34 and 10.55±0.35 Kg/m^3), FCA (0.65±0.05 and 0.76±0.10), survival (88.33± 2.89% and 90.00±5.00%), final weight (21.58±1.14g and 22.90±1.28g) in relation to the control and autotrophic. Furthermore, for water quality (NAT - 1.01 ± 0.05 mg/L and 1.03 ± 0.06 mg/L; N-NO_2 - 0.42 ± 0.07 mg/L and 0.64 ± 0.01 mg/L) and water footprint (197.54 L/kg ± 2.00 and 200.16 ± 1.15 L/kg). However, dissolved oxygen was lower in BFT and Synbiotic, when purchased as control. Microbiology showed the Synbiotic with the highest UFC values for the MYP medium (Bacillus sp. 5.50×10^5 ±3.00×10^3 CFU), the biofloc with the highest standard count (PCA-8.72×10^9 ± 1.00 $\times10^3$ CFU), enterobacteria (BEM -4.04×10^9 ± 6.10×10^6 CFU) and Gram-negative bacteria (4.67×10^7 ± 1.01×10^5 CFU), autotrophic and control, had the lowest CFU values in the samples analyzed. Therefore, we can conclude that BFT and Synbiotic technologies are promising for improving the results of zootechnical production of juvenile Nile tilapia.

Key words: fertilization, water quality, zootechnical index, microbiology.

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1-INTRODUÇÃO

1.1- CONTEXTUALIZAÇÃO DA PESQUISA

A aquicultura mundial tem crescido a cada ano e no último levantamento, atingiu a marca de 88 milhões de toneladas, dos quais, 54,4 milhões são oriundas da aquicultura continental. Com este crescimento, mesmo em meio aos imprevistos gerados pela covid-19, ocorreu o aumento do consumo per capita de peixes, que atingiu 20,2 kg em 2020 (FAO, 2022).

A piscicultura é o ramo da aquicultura em que a produção tem avançado constantemente. No Brasil, este avanço alcançou 2,3%, somando 860.355 toneladas de pescado produzido. A espécie de maior representatividade na piscicultura nacional é a tilápia, e ela continua sendo o destaque dos peixes de cultivo, com crescimento de 3% na produção nacional em relação ao ano anterior, também mantendo o país na 4ª posição no ranking mundial de maiores produtores (Peixe BR, 2023). No entanto, para que a cadeia produtiva siga de forma contínua, a produção de alevinos e juvenis é fundamental.

Em 2021, a produção de alevinos no Brasil foi de 1.431.538 milheiros (IBGE, 2022), os valores por espécie não estão disponibilizados nesse levantamento, no entanto, considerando que em termos de produção total, a tilápia representa 63,93% da produção nacional (Peixe BR 2023), com isso, espera-se que esse valor se reflita na produção de alevinos. Para que haja uma ampliação no setor produtivo, a quantidade ofertada deste insumo é fundamental, tendo em vista que além de viabilizar o amento na produção, se for ofertado na forma de juvenis, ainda diminui o tempo de cultivo nas fazendas, gerando um aumento de produtividade.

O Brasil possui uma grande área territorial e apresenta extensas bacias hidrográficas, fato este que lhe confere um grande potencial para a aquicultura (Vicente et al., 2014), porém é necessário o uso consciente desses recursos, uma vez que os sistemas de produção diferem bastante principalmente no uso de água.

Tecnologias de produção tradicionais podem apresentar um gasto de água elevado, principalmente quando comparado as tecnologias de produção intensiva com mínimo uso de água. Os modelos de produção se diferenciam de acordo com seus princípios e finalidades, e são classificados de diversas formas, com suas particularidades, vantagens e desvantagens. (Crepaldi et al., 2006). Uma grande parte das tecnologias de cultivo contam com o auxílio da fertilização, que promove o crescimento de alimento natural no ambiente (Garg e Bhatnagar, 2000; Hossain et al., 2008). No entanto todo processo de fertilização envolve a adição de nutrientes que precisam ser ciclados para que o sistema se mantenha em equilíbrio.

Em tanques ou viveiros de aquicultura, comumente há três vias de transformação do nitrogênio inorgânico: fotoautotrófico (algas), bactérias quimioautotróficas (nitrificantes) e bactérias heterotróficas agindo em conjunto e competindo pelo mesmo substrato (Ebeling et al., 2006).

No autotrófico se faz o uso de fertilizantes inorgânicos a base de nitrogênio, fósforo e potássio (NPK), onde as aplicações são feitas em quantidades apropriadas para incrementar a disponibilidade de fitoplâncton e zooplâncton nos ambientes de produção (Geiger, 1983), mas o seu uso de forma desordenada pode causar efeitos adversos na microflora do solo e na qualidade da água. E em ambientes de cultivo que apresentam a oferta de ração, pode ser desnecessário a complementação desta fertilização, uma vez que o aumento destes nutrientes pode levar a eutrofização do ambiente.

Já as tecnologias de bioflocos e o simbiótico, tem como princípio básico, fazer o controle da relação C/N através da adição de carbono orgânico na água do cultivo, para estimular o desenvolvimento de bactérias heterotróficas capazes de assimilar o nitrogênio inorgânico dissolvido na água e produzir proteína microbiana (Schneider et al., 2006; Samocha et al., 2017).

No bioflocos o crescimento microbiano serve de fonte de alimento natural para os animais, maximizando a eficiência alimentar (Rocha et al., 2012). Alguns estudos demostram que é possível a produção de alevinos de tilápia do Nilo em sistema de mínima troca de água (bioflocos - BFT) usando a relação C:N 10:1, com resultados promissores tanto nos parâmetros da qualidade de água, quanto na sobrevivência, taxas de crescimento e fator de conversão alimentar (Zapata-Lovera, et al., 2017). Pérez-Fuentes et al. (2016) relatam que relações 10:1 - 12,5:1, também se mostraram promissoras para o cultivo.

A tecnologia simbióticas é definida como uma variante do bioflocos e atua incorporando um suplemento nutricional que é uma combinação de probióticos e prebióticos, portanto, de modo geral ele é obtido através da fermentação e/ou respiração microbiana de uma fonte de carbono (probiótico), como o farelo de origem vegetal (arroz, soja, trigo) junto com probióticos (*Bacillus*, *Lactobacillus*, leveduras, etc.) e outros suplementos, trazendo melhorias na sobrevivência crescimento e eficiência alimentar (Munaeni et al., 2014; Das et al., 2017).

O uso da tecnologia de simbiótico, mostrou uma série de resultados positivos, tanto na microbiota intestinal, quanto em relação ao desenvolvimento zootécnico de camarões marinhos (Silva et al., 2021). Entretanto para produção de alevinos de tilápias existe uma lacuna de conhecimento a ser pesquisado.

Ofertar juvenis para a cadeia produtiva da tilápia é uma atividade viável, principalmente porque diminui o tempo de cultivo na fase de engorda. Contudo, para que se possa atender a essa demanda de maneira sustentável, é necessário buscar meios de otimizar a produção nas áreas já cultivadas, buscando novos insumos ou metodologias de cultivo para serem testadas e implementadas.

2 - OBJETIVO

2.1 Geral:

O presente estudo tem como objetivo avaliar a produção de juvenis de *Oreochromis niloticus*, submetidos a diferentes tecnologias de cultivo, autotrófico, simbiótico e bioflocos.

2.2 Específicos:

- Avaliar o efeito das diferentes tecnologias de cultivo (autotrófico, bioflocos e simbiótico) no desempenho zootécnico dos animais cultivados;
- Classificar, quantificar e avaliar o desenvolvimento dos principais grupos de fitoplâncton e zooplâncton nas diferentes tecnologias de cultivo;
- Avaliar o comportamento temporal dos parâmetros da água dos cultivos e a relação do uso de água por biomassa de peixe produzida.

3- HIPÓTESE

- A produção de juvenis de tilápia do Nilo, o comportamento temporal do plâncton, o uso e qualidade dos recursos hídricos são influenciados pela tecnologia de produção adotada (autotrófico, bioflocos e simbiótico).

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The culture of Nile tilapia (*Oreochromis niloticus*) juvenile at different culture technologies: Autotrophic, Bioflocs and Synbiotic

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Abstract

The supply of juvenile Nile tilapia strengthens the fish farming production chain. Therefore, this work aimed to evaluate the production of juvenile *Oreochromis niloticus* in different culture technologies: autotrophic, synbiotic, and bioflocs, through of water quality parameters, plankton groups, bacterial counts and zootechnical performance. The experiment lasted 40 days and used tilápia fry weighing 3.60 ± 0.32 g stocking density of 500 fish/m^3 and fed with commercial feed (46% crude protein and 9% lipids). Before stocking the fish, the experimental units were prepared for 30 days with inorganic (potassium nitrate and superphosphate - autotrophic - AUT) and organic (sugar - bioflocs - BFT; rice bran fermented with probiotic - synbiotic - SYNB) addition and control group (CTL). Regarding water quality parameters, temperature, salinity, dissolved oxygen (DO) and pH were within those recommended for the culture of the species. The nitrogen compounds (TAN and N-NO_2) and water footprint were lower in BFT and SYNB as compared than AUT and CTL. The phytoplankton community had significantly higher Bacillariophyta count in BFT and SYNB as compared than AUT and CLT, however Chlorophyta in AUT and Cyanophyta in BFT, SYNB and CTL, prevailed. Zooplankton showed dominance of Rotifera in all treatments, with higher values in SYNB and BFT ($p < 0.05$). BFT had the highest standard bacterial count, SYNB had the highest *Bacillus* sp. count, and AUT and CTL showed the lowest microbial counts ($p < 0.05$). The zootechnical performance: final weight, yield, SGR, FCR, feed efficiency and Fulton condition factor were higher ($p < 0.05$) in the BFT and SYNB treatments as compared than to the AUT and CTL. Regarding survival, the lowest ($p < 0.05$) was observed in the control treatment. Therefore, we can conclude that the BFT and SYNB systems are promising for improving the results of nitrogen compounds (TAN and N-NO_2) control, water footprint, plankton community, bacterial and zootechnical production of juvenile Nile tilapia.

Keywords: inorganic, organic, water quality, water footprint, plankton, bacterial, zootechnical performance.

1. Introduction

In the last decade, aquaculture has shown an important productive advance, demonstrating its essentialism to food security and global nutrition. However for this sector to continue progressing, changes in management are necessary, which involve innovation and investments in the sector (FAO, 2022).

Nile tilapia (*Oreochromis niloticus*) is one of the main aquaculture species, ranking third (4,407.2 thousand tons – 9% of the total volume) among the most cultured fish in the world (FAO, 2022). In Brazil, tilapia is the most representative species in fish farming, being responsible for 860,355 tons of fish produced in 2022. Furthermore, tilapia is highlighted in national production, with growth of 3% in relation to 2021, maintaining the country in the 4th position in the world ranking of largest producers (IBGE, 2022; Peixe BR, 2023).

The advantages of tilapia farming include its rapid growth, good meat quality and high yield, combined with economic and social benefits (Ng and Romano, 2013; Zhang et al., 2022). The growth of Nile tilapia is also linked to its tolerance to wide ranges of dissolved oxygen (DO), temperatures, and salinity, in addition to its omnivorous eating habit that favors the acceptance of live or inert foods (El-Sayed, 2019)

Despite its evident practicality in relation to water quality parameters and eating habits, the choice of appropriate production technologies, or those consistent with certain realities, can contribute to the development of the sector. The different production technologies in aquaculture have their peculiarities and can differ according to their principles and purposes. A large part of culture systems has nutrients input through inorganic and organic fertilizers, which promote the growth of natural food (Garg and Bhatnagar, 2000; Hossain et al., 2008).

The most conventional technologies adopted in aquaculture aimed at boosting plankton production by use of inorganic fertilization based on nitrogen, phosphorus and potassium (Geiger, 1983). Biofloc technology and its derivatives, on the other hand, use organic fertilization based on the input of organic carbon to maintain C:N ratios, favoring the proliferation of heterotrophic and nitrifying bacteria and improving water quality (Schneider et al., 2006; Samocha et al., 2017). Bioflocs technology (BFT) promotes the growth of microorganisms that help maintain and balance culture, such as heterotrophic bacteria, Rotifera and Protozoa. In this environment, in addition to high oxygenation, it is necessary to add organic carbon to maintain bacterial activity, which assimilates nitrogenous compounds, improving water quality. These concentrations of microorganisms serve as a natural food source for fish and shrimp, improving their zootechnical indices (Wasielesky et al., 2006; Avnimelech, 2009; Emerenciano et al., 2012; Rajkumar et al., 2016; Emerenciano et al., 2017; El-Sayed, 2021).

The use of synbiotic technology in aquaculture is relatively new and can be considered a variant of bioflocs (Khajani et al., 2023). This is premised on the combination of probiotics and prebiotics (plant meals) from fermentation and/or microbial respiration (Munaeni et al., 2014; Das et al., 2017; Romano, 2017, 2018; de Andrade et al., 2021; Santos et al., 2022). This system has presented positive data for shrimp production in the nursery (Silva et al., 2021; Santos et al., 2022; Pimentel et al., 2023) and grow-out (Huynh et al., 2018; Silva et al., 2023).

In addition to improving the fish zootechnical performance, these technologies (BFT and Synbiotic) use less water per kilogram of fish produced. Emphasizing that aquaculture production models, in addition to improving the zootechnical performance of fish, need to reduce the use of water per kilogram of animal produced, bringing more sustainability to the sector (Ahmed and Thompson, 2018), however, research comparing different culture technologies: Autotrophs, Bioflocs and Synbiotics are still scarce.

Therefore, the present study aimed to evaluate aspects of growth, planktonic community and prevalence of microorganisms, in addition to water quality and demand, in the production of *Oreochromis niloticus* in the nursery with different technologies: autotrophic, bioflocs and synbiotic.

2. Material and methods

2.1 Experimental conditions

All procedures were previously approved by the UFRPE Animal Use Ethics Committee under CEUA license nº 2698230222 (ID 000982).

The experiment was carried at the Professor Johei Koike Aquaculture Station (EAJK) of the

Department of Fisheries and Aquaculture of the Federal Rural University of Pernambuco (UFRPE) for 40 days, through a completely randomized design with the following treatments in triplicate: autotrophic (AUT), bioflocs (BFT), synbiotic (SYNB) and control (CTL).

To prepare the autotrophic system (AUT), a matrix tank with a useful volume of 200 L was used, with the addition of filtered low salinity water (5.0 g L^{-1}), chlorinated at 30 ppm and dechlorinated with aeration for 3 days. Subsequently, two fertilizer applications (1^{th} day and 10^{th} day) of 8 gm^{-3} of potassium nitrate (35% N) and 5 gm^{-3} of superphosphate (20% P_2O_5) were added to obtain an N:P ratio of 6:1 (Boyd, 1982; Boyd and Pillai, 1985; Hoa and Nhi, 2020). After 20 days, this volume was then divided into experimental units (polyethylene boxes with a useful volume of 40 L). After stocking fish, four fertilizer applications (8th day, 16th day, 24th day, and 32nd day) were addition in the experimental units. The water exchange in the AUT treatment were daily with a volume of 20% of the experimental unit to maintain the total ammonia nitrogen (TAN) concentration less than 1 mgL^{-1} (Suárez-Puerto et al., 2021), in addition dechlorinated freshwater was added to replace evaporation loss two times a week.

For bioflocs (BFT), a matrix tank with a useful volume of 200 L was used, with the addition of filtered low salinity water (5.0 g L^{-1}), chlorinated at 30 ppm and dechlorinated with aeration for 3 days. Subsequently, three fertilizer applications (1^{th} day, 10^{th} day and 20^{th} day) of 10 g comercial feed (40% Crude protein), followed by daily supplying of sugar (2.2g), according to the calculation proposed by De Schryver et al. (2008). After 30 days, this volume of 200 L was divided into experimental units (polyethylene boxes with a useful volume of 40 L), and after stocking fish, sugar was added three times a week, as a carbon source, using a C:N ratio of 10:1 (Zapata-Lovera et al., 2017). In this treatment, only 25% of water exchange from of volume experimental unit on the 20th day of culture, with the objective of maintaining TAN less than 1 mgL^{-1} (Suárez-Puerto et al., 2021), in addition dechlorinated freshwater was added to replace evaporation loss two times a week.

For Synbiotic (SYNB), a matrix tank with a useful volume of 200 L was used, with the addition of filtered low salinity water (5.0 g L^{-1}), chlorinated at 30 ppm and dechlorinated with aeration for 3 days. Subsequently, three fertilizer applications (1^{th} day, 10^{th} day and 20^{th} day) with rice bran

8 g, sugar 0.8 g, sodium bicarbonate 1.6 g, pre-treated anerobic (24h) and aerobic (24h) with a commercial microbial mix (0.1 g of the production unit, composed of *Bacillus subtilis* (2.2×10^9 $CFUg^{-1}$), *Bacillus licheniformis* (1.8×10^9 $CFUg^{-1}$) and *Bacillus* sp. 1.6×10^9 $CFUg^{-1}$) (Kayros Ambiental e Agrícola®, São Paulo, Brazil) in 1 L of freshwater, adjusted by Santos et al. (2021) and Lima et al. (2021). During the procedure, the Synbiotic (SYNB) showed pH ≥ 6.0 and a temperature between 27 and 29 °C. After 30 days, this volume of 200 L was divided into experimental units (polyethylene boxes with a useful volume of 40 L), and after stocking fish, the applications were 20% of initial application in matriz tank and was added three times a week. In this treatment, only 25% of water exchange from of volume experimental unit on the 20th day of culture, with the objective of maintaining TAN less than 1 mgL^{-1} (Suárez-Puerto et al., 2021), in addition dechlorinated freshwater was added to replace evaporation loss two times a week.

The control (CTL) only had a supply of low salinity water (5.0 g L^{-1}), chlorinated at 30 ppm and dechlorinated with aeration for 3 days was addition. In this treatment, were 20% of water exchange from of volume experimental unit every day, with the objective of maintaining TAN less than 1 mgL^{-1} (Suárez-Puerto et al., 2021).

Alkalinity correction with sodium bicarbonate ($NaHCO_3$) was also performed every five days after water analysis to reach values > 100 mg L^{-1} (BFT and SYNB treatments, Ebeling et al., 2006) and > 60 mg L^{-1} (AUT and CTL treatments, Boyd et al., 2016).

2.2 Water quality and Water footprint

Dissolved oxygen (DO), pH, and temperature were measured daily using a digital multiparametric probe (YSI™ Model 550A Dissolved Oxygen Meter, USA). Total ammonia nitrogen (TAN), nitrogen-nitrite ($N\text{-}NO_2$), nitrogen-nitrate ($N\text{-}NO_3$) and alkalinity ($CaCO_3$) were measured every five days, following APHA recommendations (2005, 2012). Settable solids were measured daily using an Imhoff cone (Avnimelech, 2009). When settleable solids (SS) were greater than 15 mgL^{-1}, a chamber settler was used.

During the trial period, all data from freshwater exchanges and repositions (to evaporation losses) were record and the total water consumption was taken (m³), and the water footprint was measure.

$$Water\ footprint = Water\ consumption\ .\ Final\ biomass^{\ -1}$$

2.3 Fish stocking and feed management

The tilápia fingerlings were obtained in a commercial hatchery (Piramirim Alevinos, Goiana - PE, Brazil) and were subsequently acclimatized for 10 days. After acclimatization, the fish were stocking density of 500 fish/m^3, 20 fish (initial weight and 3.59 ± 0.32g and length 5.60 ± 0.42cm) per experimental unit.

The fish were fed was offered three times a day, at 9:00 A.M., 1:00 P.M. and 4:00 P.M with commercial feed containing 46% crude protein and 9% lipids (Nutripiscis Starter®, Presence, Brazil). The feeding rate of 5% of the biomass adjusted during the experiment according to consumption and biomass determined by biometrics that were taken weekly

For biometrics, the fish were sedated in 75 mgL^{-1} Eugenol immersion (Vidal et al., 2008). Biometrics data were used to establish the following zootechnical parameters: final weight (W_f), final length (L_f), daily weight gain (DWG = final weight / days of cultivation), specific growth rate (SGR = 100 × [(ln average final weight − ln average initial weight) / time]), biomass gain (BG = final biomass − initial biomass), yield (biomass gain/water volume), Fulton condition factor (K = 100 × weight / $length^3$), survival (S = number of animals harvested × 100 / number of fish stocking), feed conversion ratio (FCR = feed consumption / biomass gain), and feed efficiency (FE = biomass gain / consumption of feed) (Dieterich et al., 2013; Santos et al., 2016).

2.4 Phytoplankton and Zooplankton

Plankton samples were collected on days 0, 7, 14, 21, 28, and 40 of culture days, in 500 mL plastic containers. The water was filtered with a mesh net of 250, 125 and 70 µm, where the amount of suspended solids in the sample was reduced, and it was filtered again, using a mesh of 50 µm to retain the zooplankton and a mesh of 15 µm to retain phytoplankton, with concentration in 25 mL containers. Then, a part of the sample containing 2.5 mL was fixed in 4% formalin and stored for subsequent analysis. The portion of phytoplankton was expressed in cells per milliliter (cell mL^{-}

^{1}) according to the method described by Hötzel and Croome (1999), and zooplankton was expressed in organisms per milliliter (org mL^{-1}) according to the method described in APHA (2012). Absolute abundances (cell mL^{-1} and org mL^{-1}) and relative abundances (%) were calculated for each group. Groups equivalent to 50% of the total number of organisms in the sample were considered dominant (Lobo and Leighton, 1986).

2.5 Bacteriological Analyses

At the end of culture time, following the methodology adapted from Neves et al. (2022), the fish were fasted for 24 hours and then three specimens were collected per treatment, which were anesthetized by immersion in a eugenol solution (75 mgL^{-1}) and sacrificed by sectioning the spinal cord. Each fish then had its external surface sterilized with 70% ethanol to ensure aseptic conditions. The abdominal cavity was opened with a sterile scalpel and the entire intestinal tract was exposed. The intestine was gently washed with 0.85% sterile saline to remove digestive contents and the sample was weighed and macerated with the addition of peptone water (1:9). Then, serial dilutions were made (10^{-1} to 10^{-5}) in saline solution for plating.

A 100-µl aliquot was inoculated in duplicate using the plate propagation method. Plate Count Agar - PCA (standard bacterial count - SBC), Macconkey Agar (gram-negative bacteria), Methylene and Eosin Blue Agar (enteric bacteria - ENB), Mannitol Egg Yolk Polymyxin Agar - MYP (*Bacillus* sp.) and Thiosulfate Citrate Bile Salts Sucrose Agar - TCBS (*Vibrio* sp.) were used as selective media. Plates were incubated at 30 °C for 24 hours and colonies were counted with an automatic counter.

2.6 Statistical analysis

For statistical analyses, the ORIGIN 2023b program (© OriginLab Corporation., USA) was used. Levene and Shapiro-Wilk tests were used to verify the homoscedasticity and normality of the data, respectively. One-way analysis of variance (ANOVA) was used for fish zootechnical performance data and bacteriological analyses. The repeated measures ANOVA for water quality. When significant differences were observed, Tukey's test ($p < 0.05$) was used for mean comparison.

Phytoplankton and zooplankton data were analyzed using the PRIMER 6.0 software, where abundance values were transformed into a log (x + 1), to reduce the effect of extreme values, and the Bray-Curtis index was used for similarity, cluster analysis and non-metric multidimensional scaling (nMDS) were used to observe the similarity between the phytoplankton and zooplankton communities on a temporal and spatial scale. Analysis of Similarities (ANOSIM) were performed, with 999 permutations, to identify the difference between the groups. Differences were reported as statistically significant when $p < 0.05$.

3. Results

<u>*3.1 Water quality and water footprint*</u>

The water quality parameters are shown in Table 1. No significant differences among treatments were found in terms of temperature and salinity. The dissolved oxygen (DO) values of the CTL treatment were higher as compared than AUT, BFT and SYNB. The pH values and nitrogen compounds (TAN and $N\text{-}NO_2$) were lower in BFT and SYNB, however $N\text{-}NO_3$ was higher as compared than AUT and CTL. Alkalinity and SS were higher ($p < 0.05$) in SYNB and BFT treatments and water footprint was significantly lower ($p < 0.05$) for the BFT and SYNB treatments when compared to the AUT and CTL.

Location of the table 1

<u>*3.2 Phytoplankton and zooplankton*</u>

Throughout the production cycle, the abundance of phytoplankton in the BFT and SYNB treatments was significantly higher ($p < 0.05$) than in other treatments. Up to the 21st day of culture, an increase in phytoplankton density was observed, subsequently there was decrease in density in BFT and SYNB (Figure 1).

Location of the figure 1

The phytoplankton community was distributed into five large groups, namely: Chlorophyta, Bacillariophyta, Cyanophyta, Euglenophyta, and Pyrrophyta. For AUT, the group that presented the highest densities was Chlorophyta, while in BFT, SYNB and CTL, Cyanophyta prevailed (Figure 2).

Location of the figure 2

Group analysis (ANOSIM) in Table 2, did not demonstrate significant differences in the phytoplankton community between treatments with global R = 0.323. Cluster analysis and non-metric multidimensional scaling (NMDS) revealed the formation of two groups with a cutoff point of 50%: day 1 (Group I) and days 7, 14, 21, 35 and 40 (Group II), with MDS highlighting the distance between these groups (Figures 3A and 3B).

Location of the table 2

Location of the figure 3

Throughout the production cycle, the abundance of zooplankton in the BFT and SYNB treatments was significantly higher ($p < 0.05$) than the other treatments. An increase in abundance was noticed in the BFT and SYNB treatments from the 14th day onwards (Figure 4).

Location of the figure 4

The zooplankton community was distributed into five large groups, namely: Rotifera, Cladocera, Ostracoda, Protozoa and Nematoda. For all production systems, the group that showed the highest densities was Rotifera, with more than 70% frequency, followed by Cladocera, Ostracoda, Protozoa and Nematoda, which presented the lowest relative frequencies (Figure 5).

Location of the figure 5

Cluster analysis of the zooplankton community allowed the identification of three groups with a cutoff of 20% (Figure 6A): day 1 (Group I), and days 7, 14, 21, 28, and 40 (Group II). ANOSIM in Table 3, revealed significant differences in the zooplankton community between treatments (global R = 0.033) and NMDS highlighted the distances between these groups (Figure 6B).

Location of the figure 6

Location of the table 3

3.3 Bacteriological Analyses

The Bacteriological counts are summarized in table 4. The BFT and SYNB treatments presented the highest CFU count values using Methylene Blue and Eosin Agar (enteric bacteria - ENB) and Macconkey Agar (gram-negative bacteria). Using PCA (Standard Bacteria Count - SBC), the BFT treatment presented the highest values; and with the culture medium Mannitol Egg Yolk Agar Polymyxin - MYP (*Bacillus* sp.) more CFU was observed in the SYNB treatment. No CFU were detected on Thiosulfate Citrate Bile Salts Sucrose Agar – TCBS (*Vibrio* sp.) in any of the treatments.

Location of the table 4

3.4 Fish Zootechnical Performance

The fish zootechnical performance parameters of Nile tilapia juveniles are shown in Table 5. The values of W_f, DWG, SGR, BG, yield, K, FCR and FE ($p < 0.05$) in the BFT and SYNB treatments were higher as compared than to AUT and CTL. L_f and S (%) values were lower in the control treatment ($p < 0.05$ as compared than to BFT and SYNB.

Location of the table 5

The dispersion of the fish final weight in the treatments shown in Figure 7. The results showed that in all crops the quartiles had the median in the center, showing growth symmetry. There were, however, outliers in the AUT and SYNB treatments, however in SYNB, fish weight had a greater range.

Location of the figure 6

4. Discussion

Water quality variables such as temperature, salinity, dissolved oxygen (DO) and pH were within those recommended for the culture of the species (Hussain, 2004; El-Sayed, 2006; Rebouças et al., 2016).

However, DO values were lower in biofloc and synbiotic, while within the ideal range (4–8 mg/L). This fact can be justified by increase of microbial flocs and organic matter, increasing dissolved oxygenconsumption during culture time. On the other hand, in control and autotrophic treatments, due to as daily partial water exchange, there is a lower load of organic matter and microbial community, presenting decrease dissolved oxygen consumption.

Even though Nile tilapia does not suffer any harm in its development in the water pH range between 5.5 and 9.0 (Rebouças et al., 2016), it is necessary to maintain this parameter at levels between 7.5 and 8, due to chemoautotrophic bacteria.

The pH of the water requires constant monitoring, as the transformation of TAN by heterotrophic bacteria increases the emission of CO_2 into the water, reducing the pH and the alkalinity. This is a characteristic strongly observed in synbiotic and biofloc, hence the maintenance of alkalinity at levels above 100 mg $CaCO_3$/L (Ebeling et al., 2006), to maintain the concentrations of nitrogenous compounds balanced in heterotrophic systems.

According to Summerfelt et al. (2015) and Emerenciano et al. (2017), alkalinity in high concentrations favors the assimilation of nitrogen by heterotrophic bacteria, in addition to favoring chemoautotrophic bacteria during the nitrification process. Rahman et al. (2008) reported that values between 50 and 60 mg $CaCO_3$ L^{-1} of present water buffering capacity and lower pH variation, therefore it is important to maintain total alkalinity at appropriate levels. This variable, in addition to TAN values, can contribute to greater toxicity of nitrogenous compounds (Hussain, 2004), even in AUT and CTL treatments, with frequent water exchanges. High densities were adopted in all treatments, and in these conditions, it is necessary to have greater control of pH and alkalinity, even in the nursery phase.

The AUT and CTL treatments, even with daily water exchanges, presented higher TAN values than the BFT and SYNB treatments. These data demonstrate that the combined application of organic (bran or molasses) and inorganic (sodium bicarbonate) carbon to maintain TAN below 1.0 mg/L and total alkalinity above 100 mg $CaCO_3$/L were efficient in stimulating growth heterotrophic and chemoautotrophic (nitrifying) bacteria.

Adequate combination of organic and inorganic carbon to control nitrogen compounds from of juvenile tilapia culture at high stocking densities has also been observed by Lovera-Zapata et al. (2017) and Lima et al. (2019). Karasu et al. (2005) estimated that the average lethal concentration (LC50) of ammonia for 0.5 g tilapia fingerlings was 7.8 mg N-NH_3/L for 48 hours, values well above those observed in the present study.

The lowest values of TAN and N-NO_2 and the highest value of N-NO_3 in the BFT and SYNB treatments showed more efficient technologies in the processes of transforming nitrogenous compounds when compared water exchange (AUT and CTL).

These higher values of nitrogen compounds (TAN and N-NO_2) in AUT and CTL may have contributed to a reduction in the fish zootechnical performance. Zapata- Lovera et al (2017) also observed lower survival and yield results on the fish cultute with daily water exchange compared to systems without water exchange (addition of organic and inorganic carbon).

It is worth noting that the reduced water exchange in intensive systems generates a large amount of solid waste. Emerenciano et al. (2017) describe that to produce tilapia fingerlings and juveniles, settable solids must be in the range of 5–50 mlL-1 (Imhoff cone). In the BFT and SYNB treatments, these values were within the ideal range for tilapia, however presenting higher values than in AUT and CTL. These higher values reflect a greater consumption of DO by the microbial community as well as chamber settler use, but with a lower water footprint.

The WF for the SYNB and BFT treatments were lower due to microbial management (organic and inorganic carbon input) for nitrogen compounds (TAN and N-NO2) control, reduces the need for water exchange. According to Lima et al. (2019, 2021), the time used for the chamber settler and the water footprint are directly related to the storage density and the amount of organic carbon that is added to the system to keep nitrogen compounds controlled.

According to Ray et al. (2010), concentrations of suspended solids tend to influence the amount of light in the water, favoring the emergence of specific groups of phytoplankton.

In this study, Chlorophyta, Cyanophyta, Bacillariophyta and other groups with smaller participation (Euglenophyta and Pyrrophyta) were found in all treatments.

Chlorophyta stood out in the AUT mainly due to the nitrate-based fertilization carried out at the beginning of cultivation, as it is a form of nitrogen well assimilated by this group of microalgae. As its levels remained constant in the system, due to fertilization management, this group stood out throughout the cultivation period. Application of nitrate-based fertilizers has advantages because this form of nitrogen is not toxic to animals, in addition, the system is able to completely oxidize it, influencing the emergence of Chlorophyceae and Bacillariophyta (Boyd, 1997; Barbieri and Ostrensky, 2002).

In bioflocs, where bacteria dominate, plankton can still be observed. Mohammady et al. (2023) identified Chlorophyceae and Bacillariophyta in tilapia farming in bioflocs, which reinforces the hypothesis that biofloc technology, when well-managed, presents a favorable scenario for the development of live food and improvements in water quality.

The Bacillariophyta group, mostly represented by diatoms, occurred in all treatments, undergoing changes in abundance over time. The decrease during the experimental period may have occurred due to the increase in waste and organic matter (OM) (Lima et al., 2021). This increase in OM may favor the emergence of Cyanophyta, which can assimilate ammoniacal nitrogen in order to proliferate, and this, combined with their physiological characteristics, allows them to be successful in adverse situations (Reichwaldt and Ghadouani, 2012; Yusoffe et al., 2010).

Cyanophyta were found in all treatments, with emphasis on CTL, in which there was no aid of fertilization with nitrogenous compounds (nitrate-based fertilizer), as occurred with AUT, where the incidence of Cyanophyta was lower due to dominance of Chlorophyceae. This added to the accumulation of OM results in higher TAN values, which, unlike in SYNB and BFT, control this variable through the presence of heterotrophic and chemoautotrophic microorganisms that act in the nitrification process.

The zooplankton community showed dominance of Rotifera in all treatment over time. According to Bonecker et al. (2009), Rotifera are identified as opportunists, as they consume and assimilate a wide range of food and nutrient sources, a situation observed in heterotrophic culture, in addition to having a high rate of renewal and flexibility. As for the changes suffered by the environment, this ends up reflecting its diversity and predominance.

The largest representative portions were in synbiotic and bioflocs ($p < 0.05$). De Andrade et al. (2021) found data in a synbiotic system that corroborates the results observed. The Rotifera have a high nutritional value, and this characteristic gives them importance in complementing the nutrition (Campaña-Torres et al., 2012), adittion microbial flocs that contributed for lower FCR found in biofloc and synbioic.

Conditions of imbalance between pathogen, host and environment favor the emergence of fish diseases. This risk is always present, but we can minimize or reduce it through the implementation of good management practices. In aquaculture farming systems, several species of the genus *Bacillus* are used as probiotics and the occurrence of the strains acts to reduce or inhibit the occurrence of pathogens (Wang, Tian, Yao and Li, 2008; Emerenciano et al., 2013; Samocha, 2019) and in some cases, assist in the degradation of organic matter (Panigrahi and Azad, 2007). In the present work, fish in the SYNB system showed the highest occurrence of these *Bacillus* strains, due to the addition of the microbial mixture during the experimental period, followed by smaller volumes in the BFT and AUT. Silva et al. (2016) report that probiotic bacteria, even in small quantities, are found in the fish microbiota in different culture technologies. This fact, associated with the increase in probiotics in the SYNB system, can suppress the growth of opportunistic microorganisms in the intestinal microflora.

When evaluating the standard fish bacterial counts in the different treatments, it was observed that in the BFT system the values were significantly higher, which is already characteristic, due to the greater input of organic carbon, which increases the community of bacterial flocs with a predominance of aerobic and heterotrophic microbial (De Schryver et al., 2008).

However, it is worth noting that the fish in the SYNB system presented lower values when compared to the BFT, even with similar management characteristics, differentiating themselves precisely with the presence of *Bacillus* sp., which was more evident in the SYNB. These results may indicate that the presence of these microorganisms may have suppressed the development of other bacteria in animals, which makes SYNB technology more attractive from a bacteriological point of view.

Enterobacteria and gram-negative bacteria can be found in the intestine, skin and gills of fish (Mine and Boopathy, 2011). The microbiological analysis in the intestine of the tilapia juveniles in this study shows the occurrence of these groups of bacteria, a fact that corroborates the study by Das Neves et al. (2022), who report occurrence of enterobacteria and gram-negative bacteria in juvenile Nile tilapia. In this work, these bacteria stand out in higher concentrations in the BFT and SYNB systems, when compared to CTL and AUT. The fact that these two systems have higher bacterial loads draws attention to management care, since intensive systems with OM overloads may be more susceptible to the occurrence of diseases, hence the importance addition probiotics.

Feed is one of the main costs in fish production, and higher FCR can contribute to reducing profitability. In biofloc and synbiotic treatments, through the input of carbon and lower water exchange, microbial flocs are formed, which can be a source of food for omnivorous species such as tilapia and shrimp, directly reducing FCR values and consecutively increasing feed efficiency, biomass gain and specific growth rate (Marengoni, 2006; Ayroza et al., 2011; Burford et al., 2004;

Samocha et al., 2007; Azim and Little, 2008).

This formation of microbial flocs together with better water quality contributed to better FCR and tilapia growth in the BFT and SYNB treatments, when compared to the other treatments. According to Liang et al. (2017) zootechnical performance is directly linked to the productive capacity of the animal and the culture environment in which it is located.

This greater growth and lower FCR of fish in the BFT and SYNB treatments is related to the greater plankton biomass (phytoplankton and zooplankton) observed in these treatments, in addition to the bacterial communities. These clusters of microorganisms are rich in nutrients such as amino acids and fatty acids (Xu and Pan, 2012), providing better animal yield. According to El-Kady et al. (2016) and Fernández et al. (2008) the presence of heterotrophic bacteria together with plankton in the microbial flocs favors greater fish growth.

The Fulton condition factor (K) is a body index used to express the well-being of fish (Gomiero and Braga, 2003), and takes into account that the variation in weight at a given size increases in relation to the length of the animal. In the present study, the K value was significantly higher in the SYNB and BFT treatments, indicating better well-being of fish.

This result reflects growth parameters, however is also linked to greater availability of live food and water quality. According to Santos et al. (2019) in semi-intensive culture of Nile tilapia, with the presence of live food, the Fulton condition factor (K) were higher as compared to systems with a limited presence of live food.

The better fish zootechnical performance in SYNB and BFT treatments compared to AUT and CTL with water exchange were reported by authors such as Pérez-Fuentes (2016), Zapata et al. (2017), Liu et al. (2018) and Lima et al. (2019), confirming the importance of these SYNB and BFT technologies to produce juvenile fish, especially in regions with lower water availability.

However, technologies that manage the microbial community require greater input of dissolved oxygen, control of solids and nitrogen, in addition to specialized labor. Despite proving to be more efficient from a production point of view, economic studies are necessary for a better application of such technologies.

5. Conclusion

With this work, we can observe that water quality, water footprint, temporal behavior of plankton, bacteriological parameters and fish zootechnical performace within the production of juvenile Nile tilapia are influenced by culture technologies, with emphasis on biofloc and synbiotic, which showed the best results.

Bioflocs are already widespread in aquaculture and presented results similar to other studies already carried out, proving to be a good choice for fish intensive culture.

The synbiotic technology, less widespread, also presented good results, differentiating itself from bioflocs due to the bacteriological parameters presented, which can be important data for intensive culture, since these biological interactions, especially with probiotic bacteria, can favor better animal welfare and consequently improve survival and growth rates on a large scale.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have seemed to influence the work reported in this paper.

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Appendices

Table 1: Water quality of Nile tilapia (*Oreochromis niloticus*) nurseries in autotrophic, biofloc and synbiotic.

Parameters	Treatments				ANOVA
	AUT	BFT	SYNB	CTL	P-value
DO (mg L^{-1})	6.38 ± 0.16^{a}	6.01 ± 0.07^{b}	6.00 ± 0.10^{b}	6.16 ± 0.06^{ab}	< 0.05
pH	8.29 ± 0.06^{a}	7.63 ± 0.05^{b}	7.74 ± 0.09^{b}	8.23 ± 0.04^{a}	< 0.05
Temperature (°C)	28.63 ± 0.21^{a}	28.37 ± 0.15^{a}	28.30 ± 0.20^{a}	28.43 ± 0.08^{a}	0.16
Salinity (ppt)	3.83 ± 0.07^{a}	4.28± 0.06^{a}	4.33± 0.04^{a}	3.67± 0.06^{a}	0.96
TAN (mg L^{-1})	1.85 ± 0.09^{a}	1.01 ± 0.05^{b}	1.03 ± 0.06^{b}	2.26 ± 0.49^{a}	< 0.05
N-NO_2 (mg L^{-1})	1.99 ± 0.02^{a}	0.42 ± 0.07^{b}	0.64 ± 0.01^{b}	2.01 ± 0.51^{a}	< 0.05
N-NO_3 (mg L^{-1})	88.31 ±6.38^{ab}	99.41 ± 0.80^{a}	97.33 ± 4.62^{a}	71.33 ± 5.13^{c}	< 0.05
Alk (mg $CaCO_3$ L^{-1})	62 ± 5.19^{b}	107 ± 3.05^{a}	100 ± 1.44^{a}	58.33 ± 7.64^{b}	< 0.05
SS (mLL^{-1})	7.26 ± 1.10^{b}	28.83 ± 3.21^{a}	27.17 ± 2.93^{a}	6.83 ± 1.04^{b}	< 0.05
WF (L kg^{-1})	655.36 ± 2.65^{b}	197.54 ± 2.00^{c}	200.16 ± 1.15^{c}	809.14 ± 3.21^{a}	< 0.05

Data correspond to the mean ± standard deviation. Different letters on the same line represent a significant difference using Tukey's test ($p < 0.05$). It reads: dissolved oxygen (DO), total ammonia nitrogen (TAN), nitrogen-nitrite (N-NO_2), niteogen-nitrate (N-NO_3), alkalinity (Alk), settleable solids (SS), water footprint (WF). Definition of treatment acronyms: AUT (autotrophic), BFT (bioflocs), SYNB (synbiotic) and CTL (control).

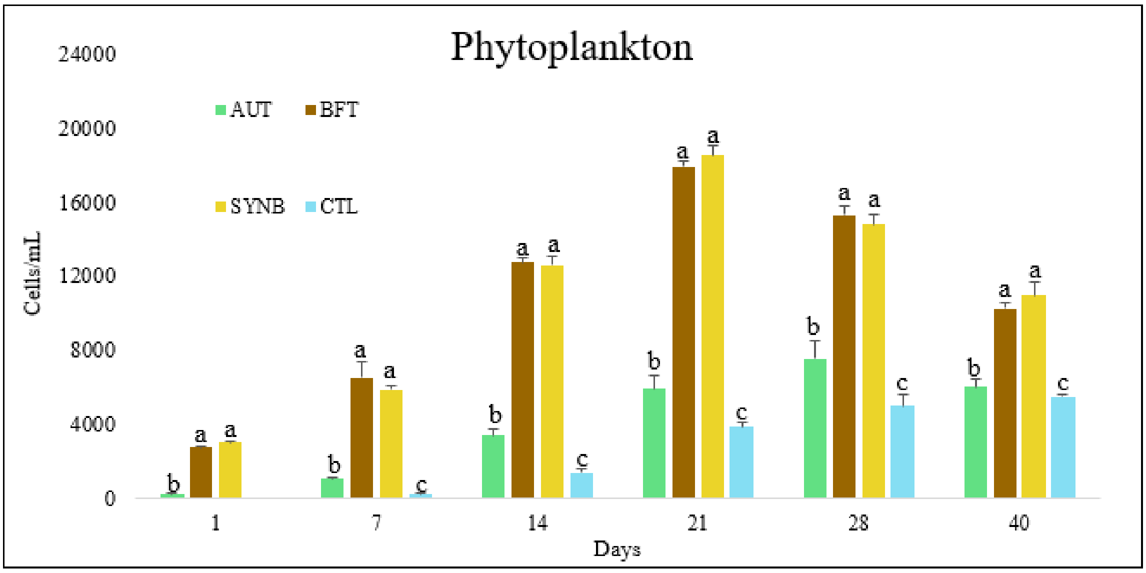

Figure 1: Abundance of the phytoplankton community over time in an *O. niloticus* nursery with autotrophic, biofloc and synbiotic. Different letters in the same period denote a significant difference according to Tukey's test ($p < 0.05$). Definition of treatment acronyms: AUT (autotrophic), BFT (bioflocs), SYNB (synbiotic) and CTL (control).

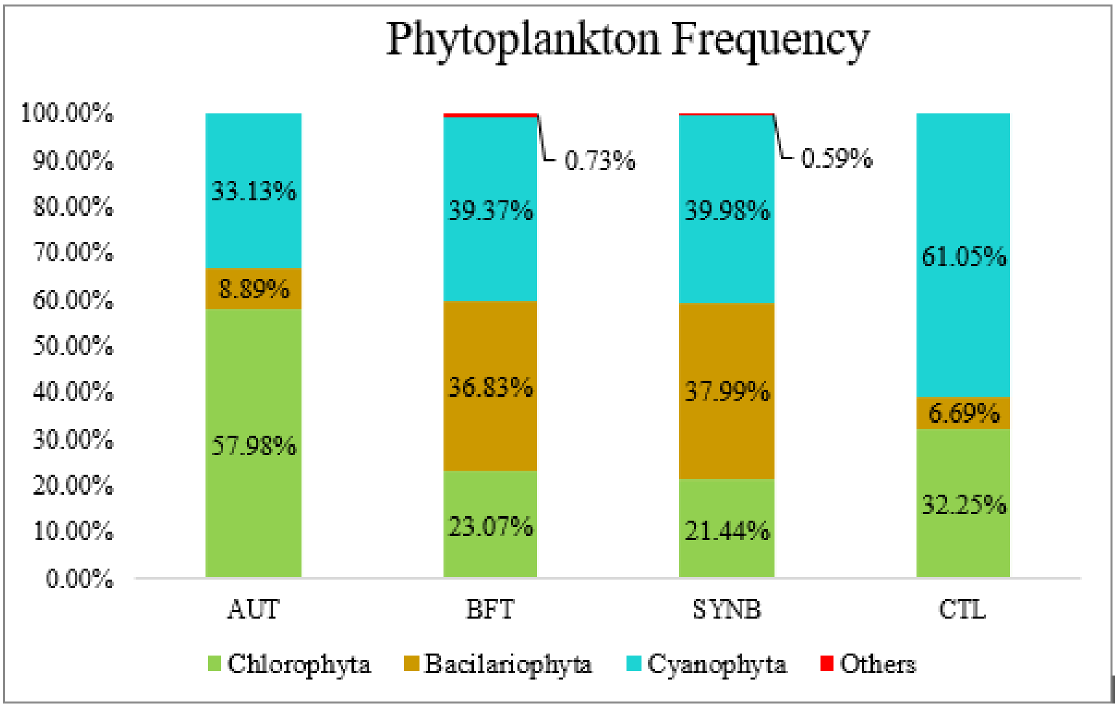

Figure 2. Relative frequencies of large phytoplankton groups in an *O. niloticus* nursery with autotrophic, biofloc and synbiotic. Others: Euglenophyta, Pyrrophyta. Definition of treatment acronyms: AUT (autotrophic), BFT (bioflocs), SYNB (synbiotic) and CTL (control).

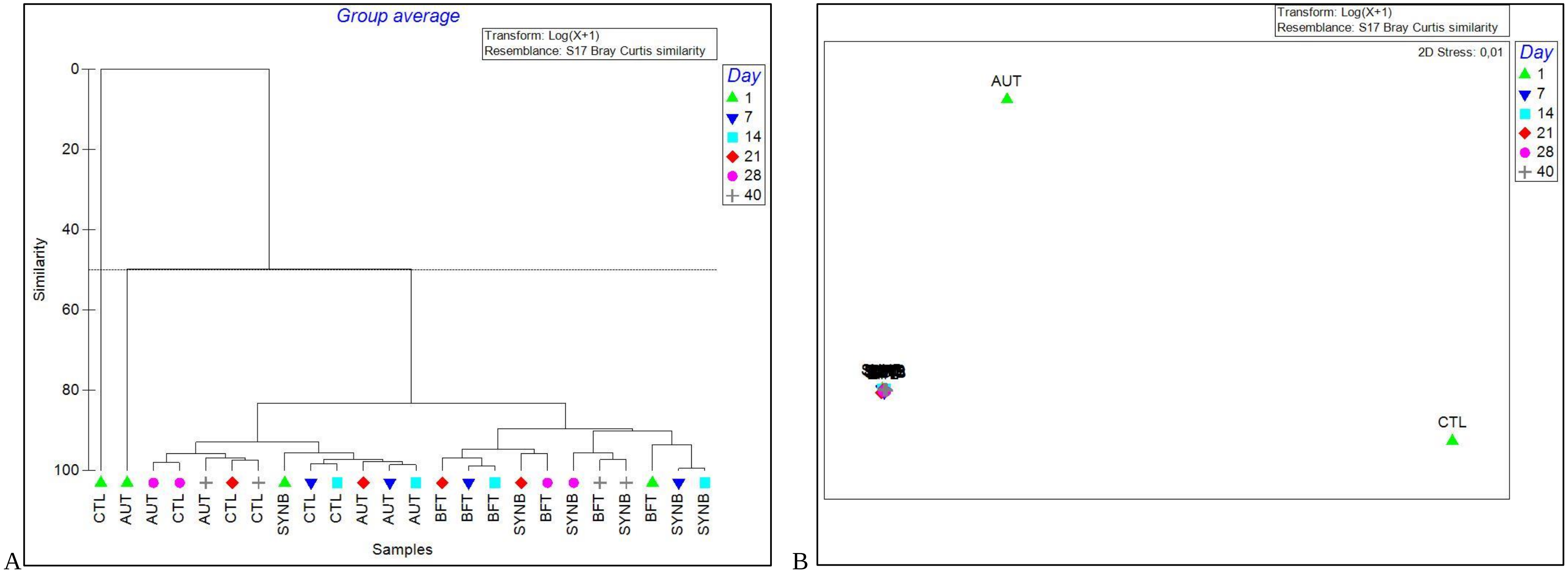

Figure 3. Cluster (A) and NMDS (B) analyzes of the phytoplankton community in an *O. niloticus* nursery with autotrophic, biofloc and synbiotic. Definition of treatment acronyms: AUT (autotrophic), BFT (bioflocs), SYNB (synbiotic) and CTL (control).

Table 2. Values related to the R statistic (p-value) found in the similarity analysis (ANOSIM) for the phytoplankton community between the autotrophic, biofloc and synbiotic.

Phytoplankton community between treatments			
Global R = 0.323	AUT	BFT	SYNB
AUT	-		
BFT	0.589	-	
SYNB	0.430	-0.017	-
CTL	0.056	0.519	0.385

Side-by-side comparisons were performed across groups for 999 permutations. R values equal to 1 indicate total dissimilarity and values equal to −1 indicate total similarity. Definition of treatment acronyms: AUT (autotrophic), BFT (bioflocs), SYNB (synbiotic) and CTL (control).

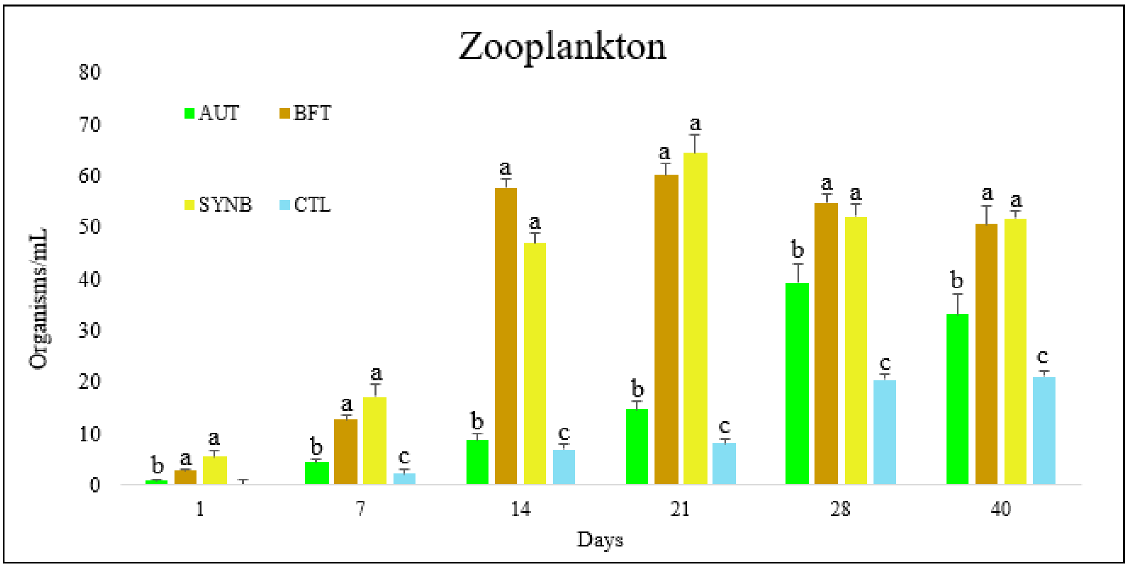

Figure 4. Abundance of the zooplankton community over time in an *O. niloticus* nursery with autotrophic, biofloc and synbiotic. Definition of treatment acronyms: AUT (autotrophic), BFT (bioflocs), SYNB (synbiotic) and CTL (control).

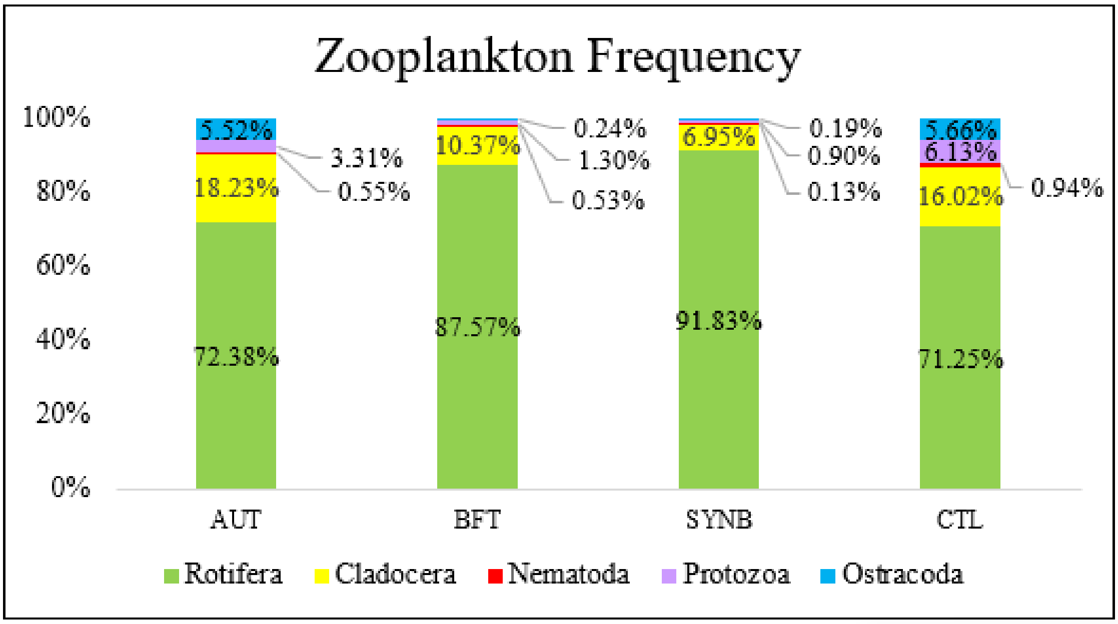

Figure 5: Relative frequencies of large zooplankton groups in an *O. niloticus* nursery with autotrophic, biofloc and synbiotic. Definition of treatment acronyms: AUT (autotrophic), BFT (bioflocs), SYNB (synbiotic) and CTL (control).

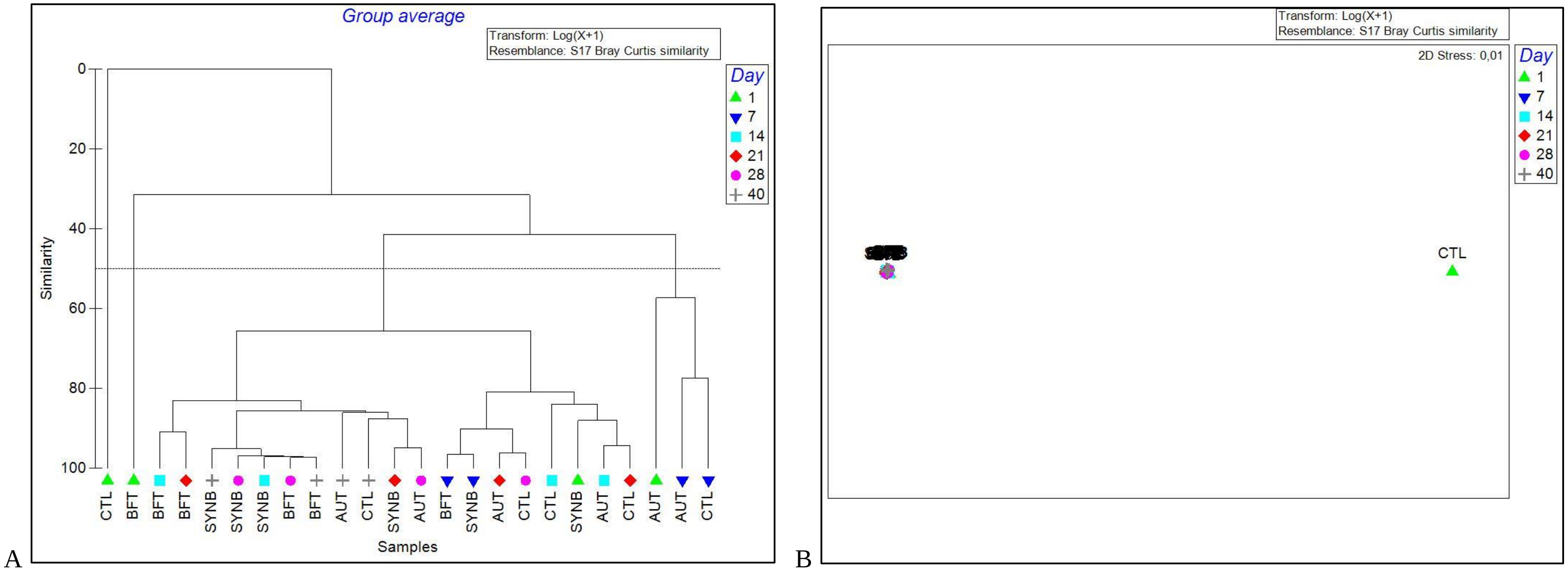

Figure 6. Cluster (A) and NMDS (B) analyses of the zooplankton community in an *O. niloticus* nursery with autotrophic, biofloc and synbiotic. Definition of treatment acronyms: AUT (autotrophic), BFT (bioflocs), SYNB (synbiotic) and CTL (control).

Table 3. Values related to the R statistic (p-value) found in the similarity analysis (ANOSIM) for the zooplankton community between the autotrophic, synbiotic, biofloc and control treatments.

Zooplankton community between treatments			
R Global = 0.033	AUT	BFT	SYNB
AUT	-		
BFT	0.056	-	
SYNB	0.033	-0.065	-
CTL	-0.080	0.143	0.111

Side-by-side comparisons were performed across groups for 999 permutations. R values equal to 1 indicate total dissimilarity and values equal to −1 indicate total similarity. Definition of treatment acronyms: AUT (autotrophic), BFT (bioflocs), SYNB (synbiotic) and CTL (control).

Table 4. Colony forming units (CFU) for intestine samples from juvenile tilapia (*O. niloticus*) referring to the autotrophic, biofloc, synbiotic and control treatments, after the experimental period of 40 days.

Bacteria / CFU	Treatment			
	AUT	BFT	SYNB	CTL
SBC	$1.19{\times}10^5 \pm 2.00{\times}10^{3c}$	$8.72{\times}10^9 \pm 1.00{\times}10^{3a}$	$1.33{\times}10^6 \pm 3.00{\times}10^{3b}$	$1.51{\times}10^5 \pm 2.30{\times}10^{4c}$
ENB	$3.10{\times}10^4 \pm 3.00{\times}10^{3b}$	$4.04{\times}10^9 \pm 6.10{\times}10^{6a}$	$1.85{\times}10^5 \pm 2.80{\times}10^{3b}$	$4.50{\times}10^4 \pm 3.00{\times}10^{3b}$
Gram negative	$2.10{\times}10^5 \pm 1.20{\times}10^{4b}$	$4.67{\times}10^7 \pm 1.01{\times}10^{5a}$	$4.05{\times}10^5 \pm 4.10{\times}10^{4a}$	$1.31{\times}10^5 \pm 1.63{\times}10^{4b}$
Bacillus sp.	$1.56{\times}10^5 \pm 3.30{\times}10^{4b}$	$1.11{\times}10^5 \pm 2.70{\times}10^{4b}$	$5.50{\times}10^5 \pm 3.00{\times}10^{3a}$	$1.55{\times}10^5 \pm 3.90{\times}10^{4b}$
Vibrio sp.	N/D	N/D	N/D	N/D

Data correspond to the mean ± standard deviation. Different letters on the same line represent a significant difference using Tukey's test ($p < 0.05$). SBC stands for Standard Bacteria Count; ENB for enteric bacteria; N/D for not detected. Definition of treatment acronyms: AUT (autotrophic), BFT (bioflocs), SYNB (synbiotic) and CTL (control).

Table 5. Zootechnical performance of Nile tilapia (*Oreochromis niloticus*) juveniles in cultures with autotrophic, biofloc and synbiotic.

Variables	Treatments				ANOVA
	AUT	BFT	SYNB	CTL	p-value
W_i (g)	3.59 ± 0.32[a]	3.59 ± 0.32[a]	3.59 ± 0.32[a]	3.59 ± 0.32[a]	0.14
L_i (cm)	5.58 ± 0.24[a]	5.58 ± 0.24[a]	5.58 ± 0.24[a]	5.58 ± 0.24[a]	0.52
W_f (g)	18.04 ± 0.25[b]	21.58 ± 1.14[a]	22.90 ± 1.28[a]	16.32 ± 1.07[b]	<0.05
L_f (cm)	10.08 ± 0.08[a]	10.23 ± 0.08[a]	10.27 ± 0.06[a]	10.37 ± 0.31[b]	<0.05
DWG (g day^{-1})	0.45 ± 0.01[b]	0.54 ± 0.03[a]	0.57 ± 0.03[a]	0.41 ± 0.03[b]	<0.05
SGR (% day^{-1})	4.05 ± 0.05[b]	4.50 ± 0.12[a]	4.61 ± 0.15[a]	3.75 ± 0.15[b]	<0.05
BG (g)	232.18 ± 20.34[b]	314.42 ± 16.28[a]	343.56 ± 16.35[a]	168.97 ± 5.83[c]	<0.05
Yield (g L^{-1})	5.76 ± 0.42[b]	7.79 ± 0.33[a]	8.72 ± 0.33[a]	4.25 ± 0.12[c]	<0.05
K	1.76 ± 0.06[b]	2.01 ± 0.10[a]	2.00 ± 0.11[a]	1.46 ± 0.19[c]	<0.05
S (%)	83.33 ± 5.77[ab]	88.33 ± 2.89[a]	90.00 ± 5.00[a]	73.33 ± 2.89[b]	<0.05
FCR	1.0 ± 0.06[b]	0.65 ± 0.05[a]	0.76 ± 0.10[a]	1.21 ± 0.02[c]	<0.05
FE	1.01 ± 0.06[b]	1.54 ± 0.12[a]	1.33 ± 0.17[a]	0.80 ± 0.01[c]	<0.05

Data correspond to mean ± standard deviation. Different letters on the same line represent a significant difference ($p < 0.05$) using Tukey's test. It reads: initial weight (W_i), initial length (L_i), final weight (W_f), final length (L_f), daily weight gain (DWG), specific growth rate (SGR), biomass gain (BG), Fulton condition factor (K), survival (S), feed conversion ratio (FCR) and feed efficiency (FE). Definition of treatment acronyms: AUT (autotrophic), BFT (bioflocs), SYNB (synbiotic) and CTL (control).

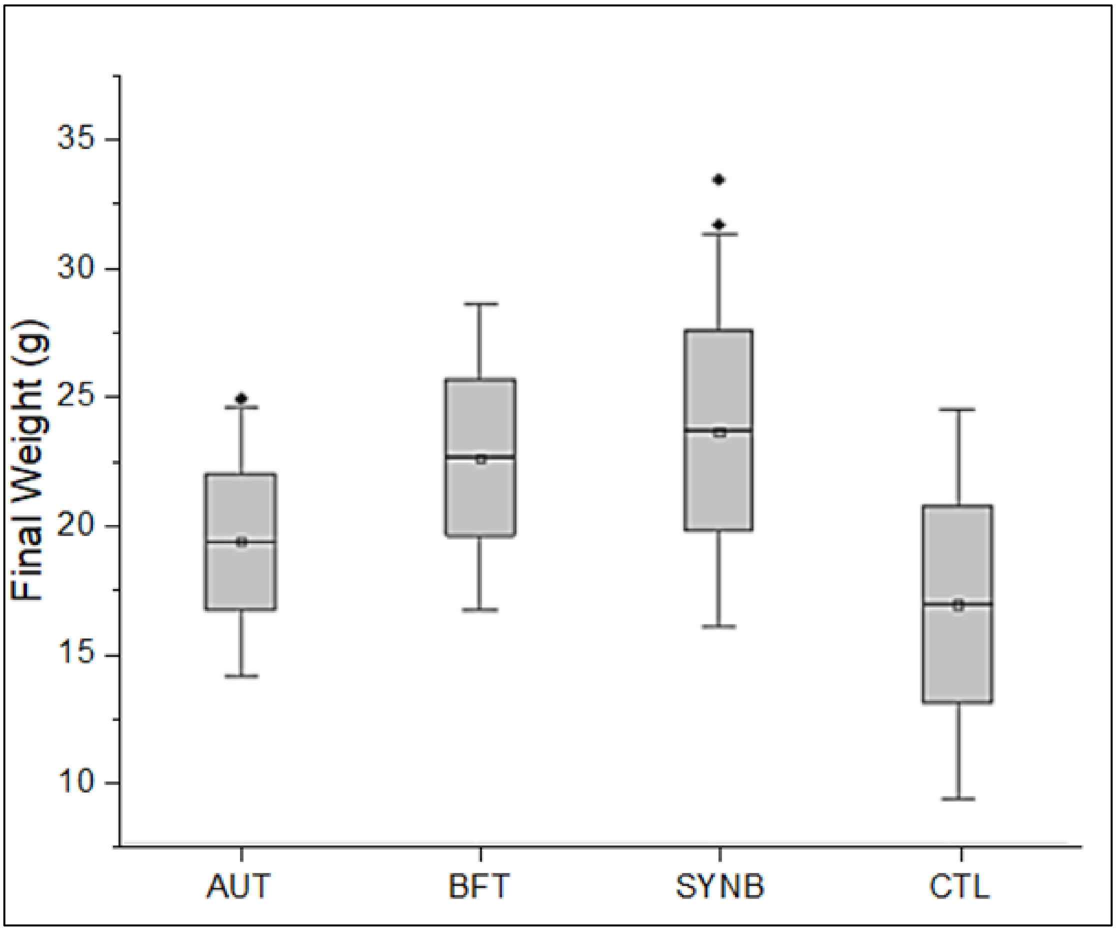

Figure 7. Boxplot of the final weight (g) of tilapia juveniles cultured in autotrophic, biofloc, synbiotic and control. Definition of treatment acronyms: AUT (autotrophic), BFT (bioflocs), SYNB (synbiotic) and CTL (control).

5- CONSIDERAÇÕES FINAIS

Com esse trabalho, podemos observar que o comportamento temporal do plâncton a qualidade e a demanda hídrica dentro da produção de juvenis de tilápia do Nilo, são influenciados pela tecnologia de cultivo. E com isso, notamos que cada modelo de cultivo apresenta suas peculiaridades e desafios.

O bioflocos já é bem difundido na aquicultura e apresentou resultados semelhantes a outros estudos já realizados, e mais uma vez se mostrou uma excelente escolha para quem busca produção intensiva.

O simbiótico além de ter apresentado resultados promissores no campo zootécnico, também apresentou bons resultados para o uso e a qualidade de água na produção e na microbiologia. Esse modelo por ser relativamente novo dentro da piscicultura, ainda necessita de mais estudos para ser aprimorado e introduzido amplamente no dia a dia da produção. Para isso são necessários estudos que desenvolvam ou aprimorem as metodologias, de modo a torná-lo cada vez mais viável e difundido.

Os modelos que fazem uso de bactérias heterotróficas como o bioflocos e simbiótico, apresentaram neste estudo resultados superiores, mesmo dependendo de oxigenação constante, e mão de obra especializada.

Também se conclui que o modelo autotrófico mesmo com as suas limitações e manejo diário, ainda se apresenta como uma boa forma de produção, para aqueles que não tem acesso a diferentes tecnologias de cultivo.

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