UNIVERSIDADE FEDERAL RURAL DE PERNAMBUCO

PRÓ-REITORIA DE PESQUISA E PÓS-GRADUAÇÃO

PROGRAMA DE PÓS-GRADUAÇÃO EM RECURSOS PESQUEIROS E AQUICULTURA

PRODUÇÃO DE “BABY” TAMBAQUI (*Colossoma macropomum*) E MICROVERDES DE RÚCULA (*Eruca sativa*) EM SISTEMAS DE AQUAPONIA: DESEMPENHO E VIABILIDADE ECONÔMICA

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Dedicatória

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Resumo

A aquaponia é uma atividade sustentável que têm crescido mundialmente nos últimos anos, como uma alternativa social para promover a segurança alimentar entre a população economicamente menos favorecida. O objetivo desse estudo foi desenvolver aquaponia em microescala com uma espécie nativa, o tambaqui (*Colossoma macropomum*), associado ao cultivo de microverdes, uma tendência agroalimentar, com a rúcula (*Eruca sativa*), visando a produção familiar de subsistência. Durante 70 dias, foi acompanhado o desempenho do crescimento de 80 juvenis de tambaqui (peso inicial médio = 61,88g ± 8,31g) para a obtenção do “baby fish” (≥ 300g). Dois tratamentos foram testados com duas estruturas hidropônicas, *Nutrient Film Technique* (NFT) e *Floating Raft Technology* (FRT) com quatro repetições. A sobrevivência dos tambaquis foi de 100% em ambos os tratamentos e algumas alterações na qualidade de água foram observadas ao longo do experimento. O peso final dos tambaquis (NFT = 136,38g ± 35,67g; FRT = 116,5g ± 24,63g) foi abaixo da média esperada, possivelmente devido a fatores associados à qualidade da água. As microverdes tiveram melhor desempenho nas estruturas NFT (157,38g ± 21,74g; 6,68cm ± 0,17cm) em relação a FRT (41g ± 6,18g; 4,46cm ± 0,58cm), definindo a melhor unidade hidropônica para o cultivo de microverdes de *E.sativa*. Por fim, o estudo de viabilidade econômica foi elaborado considerando os gastos com estrutura, energia elétrica e insumos, e uma renda familiar mensal equivalente a um salário de US$ 239,37, porém em nenhum cenário cogitado foi possível considerar a aquaponia como uma atividade viável no combate a insegurança alimentar entre famílias de baixa renda.

Palavras-chave: aquaponia; *Colossoma macropomum*; microverdes; *Eruca sativa*; segurança alimentar.

Abstract

Aquaponics is a sustainable activity that has grown worldwide in recent years as a social alternative to promote food security among the economically disadvantaged population. The objective of this study was to develop micro-scale aquaponics with a native Brazilian species, the tambaqui (*Colossoma macropomum*), associated with the cultivation of microgreens, an agro-food trend, with arugula (*Eruca sativa*), aiming at the viability of subsistence family production. For 70 days, the growth performance of 80 tambaqui juveniles (average initial weight = 61.88g ± 8.31g) was monitored to obtain “baby fish” (≥ 300g). Two treatments with two hydroponics structures, Nutrient Film Technique (NFT) and Floating Raft Technology (FRT), in four replications were tested. Survival of tambaquis was 100% in both treatments and some changes in water quality were observed throughout the experiment. The final weight of tambaquis (NFT = 136.38g ± 35.67g; FRT = 116.5g ± 24.63g) was below the expected average, possibly due to factors associated with water quality. The microgreens performed better in the NFT structures (157.38g ± 21.74g; 6.68cm ± 0.17cm) compared to the FRT (41g ± 6.18g; 4.46cm ± 0.58cm), defining the best hydroponic unit for the cultivation of *E. sativa* microgreens. Finally, the economic feasibility study was carried out considering the expenses with structure, electricity and inputs, and a monthly family income equivalent to a wage of US$ 239.37, but in none of the scenarios considered was it possible to consider aquaponics as an activity viable in combating food insecurity for those families.

Keywords: aquaponics; *Colossoma macropomum*; microgreens; *Eruca sativa*; food security.

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1- Introdução

A aquicultura tem se consolidado como a atividade capaz de atender a demana mundial de proteína animal (FAO, 2022). A produção nacional de peixes por aquicultura no ano de 2021 chegou a atingir um total de 841.005 toneladas, 4,7% a mais do que em 2021 (PEIXEBR, 2022). Ainda de acordo com a PEIXEBR, desse total, 31,2% correspondeu à produção de peixes nativos (262.370 toneladas), apresentando um declínio de 5,85% com relação ao ano anterior.

O cultivo de peixes nativos no Brasil ainda é incipiente, uma vez que não há pacotes tecnológicos adequados para produção em massa da maioria das espécies (BALDISSEROTTO, 2020). As ações de incentivo ao cultivo de peixes nativos estão atreladas à redução do risco ambiental causado pela inserção ou escape de espécies exóticas nos ecossistemas brasileiros (GUBIANI *et al.*, 2018; FONSECA *et al.*, 2017).

A sustentabilidade da aquicultura depende da redução dos impactos negativos causados pelos seus efluentes, ricos em nutrientes, principalmente nitrogênio e fósforo, através da reutilização da água. Desta forma, sistemas de cultivo ambientalmente seguros vêm sendo desenvolvidos, a fim de potencializar o desenvolvimento da produção agrícola sustentável (GODDEK *et al.*, 2015).

A aquaponia é caracterizada como a integração da hidroponia e da aquicultura em sistema de recirculação de água (LOVE *et al*., 2015b; RAKOCY *et al.*, 2003a). Neste sistema, a ração ingerida e metabolizada pelos peixes se dissolve na água que, rica em resíduos da piscicultura, fornece nutrientes para o crescimento de plantas (GODDEK *et al.*, 2015). Ainda nesse sistema, as bactérias presentes nos biofiltros e as raízes das plantas mantêm a a qualidade da água para os peixes, desempenhando papel na oxidação do nitrogênio na forma de nitrogênio amoniacal total tóxico (NH_3 + NH_4^+), convertendo-o em nitrito e, finalmente, em nitrato não tóxico por meio da nitrificação aeróbia (TANIKAWA *et al.*, 2018; WONGKIEW *et al.*, 2017).

Os componentes essenciais de um sistema aquapônico são o tanque de criação de peixes, o decantador, o biofiltro e a unidade hidropônica (RAKOCY, 2012b). Os microrganismos no biofiltro, nas raízes das plantas e na água em recirculação liberam e convertem os nutrientes (por exemplo, amônia em nitrito e este, em nitrato) e as plantas os assimilam, tratando assim a água, que retorna de volta para o componente de aquicultura do sistema.

A aquaponia, enquanto modelo de inovação, já foi avaliada em 2015 pelo Parlamento Europeu como uma das dez tecnologias capazes de fazer a diferença na vida da população e da economia (FRUSCELLA *et al.*, 2021; VAN WOENSEL & ARCHER, 2015). As vantagens do emprego desse tipo de sistema já são descritas por diversos estudos (MARTINELLI *et al.*, 2019; KÖNIG *et al.*, 2018; JUNGE *et al.*, 2017) e incluem: um baixo custo de produção em relação à produtividade, a redução na emissão de efluentes, e a adaptação a áreas com limitações de solo, além de diminuir a insegurança alimentar.

Dois tipos de modelos, cada um com sua particularidade referente à absorção de nutrientes e fixação das raízes, são os mais comumente utilizados:, as canaletas e as bandejas flutuantes (HOSHINA, 2019). O sistema de canaletas (NFT – *Nutrient Film Technique*) é o modelo mais empregado em cultivos de hortaliças e consiste no alojamento das raízes em canais tubulares que permitem a passagem de água entre as ramificações, mantendo o contato parcial da planta com a água nutrida e preservando a respiração vegetal (HOSHINA, 2019; MOHAMMED & SOOKOO, 2016). Já o sistema de bandejas flutuantes (*Floating Raft System*) utiliza placas de material de baixa densidade que flutuam e suportam os vegetais dentro de orifícios na sua estrutura, fazendo com que as raízes se mantenham submersas por completo, havendo a necessidade de uma oxigenação artificial ou, alternativamente, parcialmente submersas, o que eliminaria a oxigenação extra (SIQUEIRA *et al.*, 2018; KODAMA, 2015).

A versatilidade dos sistemas aquapônicos permitem sua utilização com uma grande variedade de peixes e vegetais. De acordo com LOVE *et al.* (2014), são cultivados em aquaponia as tilápias, os peixes ornamentais, camarões, lagostins, pacu, lambari, carpas e o tambaqui.

O tambaqui (*Colossoma macropomum*) se destaca em todo o país, representando cerca de 36% do total de peixes nativos produzidos em 2020 com aproximadamente 100.000 toneladas (IBGE, 2020). O tambaqui é um caracídeo característico da bacia Amazônica que é bastante apreciado na culinária por sua carne saborosa (DE LIMA *et al.*, 2018; CARTONILHO & JESUS, 2011). A produção em cativeiro de *C. macropomum* se deu principalmente pelo elevado consumo por parte da população regional, encontrando na aquicultura um caminho para atender as demandas do mercado consumidor (MORAIS & O'SULLIVAN, 2017).

Do ponto de vista produtivo, o cultivo de tambaqui tem suas vantagens, pois se trata de uma espécie rústica de fácil adaptação aos sistemas de aquicultura convencionais, suportando baixos níveis de oxigênio dissolvido ($\leq$1 mg.L^{-1}) e níveis elevados de amônia (até 0,46 mg.L^{-1}), além da resistência a altas temperaturas, enfermidades e manuseio (FERREIRA *et al.*, 2021; RODRIGUES, 2014). A espécie também possui uma dieta predominantemente onívora, ou seja, é possível atender às demandas nutricionais da espécie com rações mais baratas, formuladas a partir de produção primária, em contraste às rações de peixes carnívoros que demandam insumos mais onerosos (TEJPAL, 2020; DAIRIKI *et al.*, 2018; STONE, 2003);

O valor comercial agregado ao produto final tende a compensar, uma vez que se pode obter tambaquis de até 2,0 kg em ciclos de 8 a 12 meses devido a fatores como o seu rápido crescimento e ótima conversão alimentar (GALO *et al.*, 2022; CORREA *et al.*, 2018).

Também é possível encontrar demanda ainda em fase juvenil (“*baby fish tambaqui*” ou tambaqui curumim), como proteína principal em pratos executivos, muito comum em bares e restaurantes, da região Norte do Brasil, em que o peixe a partir de 300 gramas acompanha as guarnições do prato (DA COSTA *et al.*, 2017). Essa prática pode vir a ser interessante aos sistemas de cultivo por encurtar os ciclos de produção, baratear os insumos e ainda conseguir atender à demanda do mercado (MACHADO *et al.*, 2018).

Em sistemas aquapônicos, as plantas mais comumente cultivadas são a alface (*Lactuca sativa*), a rúcula (*Eruca sativa*) e algumas ervas (OZIEL & OZIEL, 2013), que são excelentes culturas devido ao alto preço de mercado e ciclos de produção curtos (SANTOS, 2020; RAKOCY, 2007a). Essas culturas apresentam necessidades nutricionais baixas e elevada capacidade de armazenamento de água em suas raízes quando comparadas a outras hortaliças, e estão bem adaptadas aos sistemas aquapônicos (BIAZETTI FILHO, 2018; BUZBY *et al.*, 2016; BLIDARIU & GROZEA, 2011).

A rúcula tem seu destaque também pela riqueza nutricional, contendo fósforo, enxofre, ferro, vitaminas A e C, além de algumas proteínas (GRANJA, 2018) e seus benefícios vão desde a complementação nutricional até mesmo o combate ao câncer (SHUBHA *et al.*, 2019). No Brasil, os dados de produção agropecuária do IBGE (2017) indicaram uma produção de 40.527 toneladas de rúcula, correspondente a 140.746 mil reais, distribuídas em 20.567 unidades de cultivo ao longo do país e sendo São Paulo o Estado com a maior produção. Pernambuco, também em 2017, produziu 272 toneladas (0,7% do montante nacional) em 250 instalações de produção, com receita de R$ 554 mil reais.

Uma modalidade de cultivo de plantas em aquaponia que vêm ganhando destaque nos últimos anos são os chamados microverdes (“*microgreens*” ou mudas comestíveis), que consiste da produção de hortaliças com a colheita realizada precocemente, dias após sua germinação (WEBER, 2017). São vegetais saborosos e ricos em nutrientes (cerca de 40 vezes mais nutritivos do que em suas fases finais de cultivo), contendo fitonutrientes como vitaminas C e K, betacaroteno e alfa tocoferol, além de minerais (ferro, magnésio, manganês, cobre, zinco, selênio, sódio, molibdênio e fósforo) (DODE *et al.*, 2021; RENNA *et al.*, 2018b; XIAO *et al.*, 2012). Essa modalidade trouxe consigo novos horizontes para a culinária, tanto pelo visual harmônico como pela riqueza nutricional, sendo bastante apreciada pelo mercado vegano e vegetariano, além de trazer novos conceitos de educação alimentar (RENNA *et al.*, 2017a).

As vantagens de produção das microverdes estão nos ciclos extremamente curtos de produção (7 a 14 dias), que por sua vez promovem o menor consumo de água quando comparado ao uso hídrico em um ciclo completo dos vegetais, e também na logística de cultivo por não haver demanda por espaço, sendo facilmente adaptados a qualquer recipiente que permita sua instalação (SREENIVASAN, 2020; WEBER, 2017).

Em zonas urbanas, desprovidas de terrenos e recursos hídricos em abundância, nas quais o contraste de poder aquisitivo é evidente, a aquaponia pode ser uma alternativa para suplementar a demanda nutricional de grupos sociais menos favorecidos (DOS SANTOS, 2016).

Neste sentido, o presente estudo teve como objetivo utilizar a aquaponia comparando dois sistemas, bandejas flutuantes e canaletas, na produção de baby tambaqui e microverdes de rúcula e avaliar sua viabilidade em zonas urbanas.

1.1- Objetivos

1.1.1-Geral

Avaliar o desempenho do “*baby fish tambaqui*” (juvenil de *C. macropomum*) e das microverdes de rúcula (*E. sativa*) em sistema aquapônico.

1.1.2-Específicos

- Determinar parâmetros de interesse zootécnico no cultivo em aquaponia de *C. macropomum* (taxa de crescimento específico; fator de conversão alimentar; ganho de biomassa e sobrevivência);
- Determinar parâmetros de interesse fitotécnico importantes na produção aquapônica de microverdes da rúcula, *Eruca sativa* (índice de germinação, comprimento padrão e massa fresca);
- Identificar um modelo de cultivo com melhor desempenho para a produção dos microverdes de *E. sativa*;
- Estimar a viabilidade econômica do sistema de cultivo aquapônico empregado, visando o cultivo familiar de subsistência.

1.2- Hipóteses

O cultivo de juvenis de tambaqui (*C. macropomum*) associado à microverde de rúcula (*E. sativa*) em aquaponia é viável produtiva e economicamente para comunidades urbanas de baixa renda.

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Challenges and limitations of micro-scale aquaponics with baby tambaqui (*Colossoma macropomum*) and arugula microgreens (*Eruca sativa*) for subsistence family production

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Highlights

- Baby tambaqui size (*Colossoma macropomum*) has not been achieved in small scale aquaponics;
- Arugula microgreens (*Eruca sativa*) performed better in NFT (*Nutrient Film Technique*) structures;
- Aquaponics as a subsistence activity is not yet advantageous.

ABSTRACT

Aquaponics is an activity that has grown worldwide in recent years as a social alternative to promote food security among the economically disadvantaged population. The objective of this study was to develop micro-scale aquaponics with a native Brazilian species, the tambaqui (*Colossoma macropomum*), associated with the cultivation of microgreens, an agro-food trend, with arugula (*Eruca sativa*), aiming at the viability of subsistence family production. For 70 days, the growth performance of 80 tambaqui juveniles (average initial weight = 61.88g ± 8.31g) was monitored to obtain “baby fish” (≥ 300g). Two treatments with two hydroponics structures, Nutrient Film Technique (NFT) and Floating Raft Technology (FRT), in four replications were tested. Survival of tambaquis was 100% in both treatments and some changes in water quality were observed along the experiment. The final weight of tambaquis (NFT = 136.38g ± 35.67g; FRT = 116.5g ± 24.63g) was below the expected average, possibly due to factors associated with water quality. The microgreens performed better in the NFT structures (157.38g ± 21.74g; 6.68cm ± 0.17cm) compared to the FRT (41g ± 6.18g; 4.46cm ± 0.58cm), defining the best hydroponic unit for the cultivation of *E. sativa* microgreens. Finally, the economic feasibility study was carried out considering the expenses with structure, electricity and inputs, and a monthly family income equivalent to a wage of US$ 239.37, but in none of the scenarios considered was it possible to consider aquaponics as an activity viable in combating food insecurity for those families.

Keywords: aquaponics; *Colossoma macropomum*; microgreens; *Eruca sativa*; food security.

1. Introduction

Aquaponics is a production activity that combines aquaculture and hydroponics integrated in a water recirculation system, where the food ingested and metabolized by the fish dissolves and provides nutrients for plant growth (Love *et al.*, 2015b; Goddek *et al.*, 2015; Rakocy *et al.*, 2003a). This farming model has mainly developed as a promising solution to combat global food insecurity (David *et al.*, 2022; Baganz *et al.*, 2021). Due to its low space demand structure, its adaptation to urban spaces is encouraged to attend economically disadvantaged populations, whose families participate in the entire process for their own consumption using aquaponics (Wirza & Nazir, 2021; Dos Santos, 2016).

In the African continent, some urban aquaponics initiatives have already been tested, as in Nigeria which faces one of the highest rates of migration to urban areas due to climate conditions that make rural production unfeasible and increase the incidence of hunger and food insecurity (Benjamin *et al.*, 2021a,b). However, there are still wide gaps in the consolidation of production systems in these regions, such as the significantly high initial investment, as many families cannot afford the costs of construction materials and depend on public policies (Okomoda *et al.*, 2022).

The hunger and food insecurity situation worldwide has worsened alarmingly. In the post-pandemic scenario, around 828 million people (9.8% of the global population) were affected by hunger in 2021, while approximately 2.3 billion people (29.3% of the world's population) suffer from moderate or severe food insecurity, according to the United Nations report (2022).

Urban aquaponics presents itself as a path to combat this situation, however, studies are needed to address the necessary sizing and initial investment for an executable project. Experimental actions for this purpose have already been developed and face similar barriers in terms of occupying less space and alternatives that make the investment viable for families (Brewer *et al.*, 2021; Silva & Van Passel, 2020).

The cost of electricity can also be an obstacle to its viability, and a solution may lie in investing in renewable energy generation such as solar power (Nagayo *et al.*, 2017). The application of photovoltaic panels in aquaponic systems goes beyond reducing costs with conventional electricity, and it is also important for regulating temperature within the farming areas, especially in regions with seasonal climate (Goddek *et al.*, 2015). In temperate zones, for example, one of the functions of solar panels is to keep heaters inside the greenhouses to establish a comfortable temperature for the fish, since conventional energy costs tend to be expensive (Mullins *et al.*, 2016).

The choice of fish species to be cultivated in aquaponics is also important when considering space limitations, with species tolerant to significant densities, suspended solids concentrations, and dissolved compounds in the water being preferred (Pinho *et al.*, 2021). The tambaqui (*Colossoma macropomum*) is a native Brazilian species widely cultivated in conventional aquaculture systems and has potential for aquaponic cultivation due to its robustness, enduring low levels of dissolved oxygen, fluctuations in ammonia concentration, and high temperatures (Ferreira *et al.*, 2021; Rodrigues, 2014). In the northern region of the country, the tambaqui is also consumed in the juvenile stage ("baby fish tambaqui" or tambaqui curumim), found in executive meals in bars and restaurants, where a whole unit of the fish from 300 grams accompanies the meal (Da Costa *et al.*, 2017). The expansion of baby fish farming may be interesting within the family subsistence aquaponics by shortening production cycles and accelerating access to protein for consumption (Machado *et al.*, 2018).

In the selection of vegetables, the determining factor is the plant's adaptation to the hydroponic structure selected for integrating the aquaponics system (Masabni & Niu, 2022). Among the models used most frequently are the *Nutrient Film Technique* (NFT) and the *Floating Raft Technology* (FRT) systems. The NFT system involves the use of tubular channels with holes that allow the accommodation of vegetables or a substrate in contact with a water flux from the recirculation system (Mir *et al.*, 2022). The FRT system, on the other hand, uses low-density plates that float in boxes containing water from the system and support the vegetables or substrates within holes in its structure, which remain partially or entirely submerged (Siqueira *et al.*, 2018).

Arugula (*Eruca sativa*), for example, is commonly grown in aquaponic systems (Oziel & Oziel, 2013) and has value-added, as well as short production cycles (Dos Santos *et al.*, 2020; Rakocy, 2007b). Arugula stands out for its nutritional richness (P, S, Fe, vitamins A and C) and its benefits range from nutritional supplementation to cancer-fighting properties (Sharma *et al.*, 2022; Shubha *et al.*, 2019). From the perspective of vegetable cultivation, a recent agricultural trend has been the production of microgreens (edible seedlings), which consists of producing vegetables with early harvesting, between 7 to 14 days after germination (Weber, 2017). They are tasty and nutrient-rich, about 40 times more nutritious than their final stages of growth, containing phytonutrients (vitamins C and K, beta-carotene, and alpha-tocopherol) and minerals (Fe, Mn, Mg, Na, Mo, and P) (Dode *et al.*, 2021; Renna *et al.*, 2018; Xiao *et al.*, 2012). In addition, the nutritional demand of microgreens tends to be low, since the seed itself is responsible for the plant's nutrition until its roots are properly formed (Mir *et al.*, 2017). The cultivation of microgreens in aquaponics allows the weekly supply of vegetables as a dietary supplement.

Based on these premises, the present study aimed to evaluate the economic feasibility of a small-scale aquaponic production system using juvenile tambaqui and arugula microgreens . for low-income families living on a monthly wage of US$ 239.37.

2. Materials and methods

2.1. Material collection

Eighty *C. macropomum* juveniles were randomly selected without sexual determination, with an average initial weight of 53.6 g (± 6.59 g), from the Continental Aquaculture Station Prof. Johei Koike, located in the Department of Fisheries and Aquaculture at the Federal Rural University of Pernambuco - UFRPE (8° 1' 11.384" S 34° 56' 42.703" W). After a quarantine period of 20 days, the animals were transferred to experimental aquaponic units installed in a greenhouse near the collection site.

2.2. Experimental structure

Two farming systems were developed, one with NFT and the other with FRT structures. Each treatment was composed of four replicates, totaling eight experimental units, with the following structure: a circular tank with 200 L of useful volume for fish farming, a submersible pump (800 $L.h^{-1}$), a mechanical filter with perlon mesh for solids retention, a biological filter with expanded clay pebbles (25 L) for bacterial activity, with dimensions established based on Foucard's calculations (2019), and the corresponding hydroponic unit (Figure 1). Continuously, water from the tank was pumped to the mechanical filter at a flow rate regulated at 3 $L.min^{-1}$, flowing to the biological filter which, after performing its role of reducing organic and inorganic compounds in the system, distributed the water by gravity to the hydroponic units. After irrigating these units, the water returned to the fish cultivation tank, also by gravity, oxygenating the water and restarting the water cycle of the system.

For the FRT system, each replicate contained three rectangular boxes with a useful volume of 25 L, and polystyrene plates were used as a floating structure, attaching 11 circular pots with fragmented expanded clay pebbles on each plate, which served as a substrate for the germination of microgreens of arugula (Figure 1). The pots in the FRT system were arranged tangentially to the water surface, in order not to soak the substrate and allow the germinated roots to breathe, dispensing the artificial oxygenation of the plants. In the NFT system, each replicate was composed of three tubular channels of 1.40 meters in length, also with 11 holes each, in which pots of the same substrate were installed for seed germination.

The electricity for the eight experimental units was provided by a stationary battery of 150 $A.h^{-1}$ connected to a monophase 400 W photovoltaic panel, responsible for powering the 12-volt submersible pumps (20 W), with the energy conversion performed by a charge controller (30 A). All systems were connected, without the presence of fish and the substrates of the hydroponic units, for 20 days for the prior maturation of nitrifying bacteria in the biofilters.

2.3. Fish and microgreen management

After the quarantine period, each tank was stocked with 10 juveniles of tambaqui (61.88 g ± 8.31 g) for a 70-day growout period, in order to reach an average weight similar to that of fish characterized as "baby tambaqui", approximately 300 g (Machado *et al.*, 2018). The stocking density was defined according to the recommendations of the tambaqui farming manual from the Brazilian Agricultural Research Corporation - EMBRAPA (Corrêa *et al.*, 2018). The animals were fed with commercial feed containing 36% crude protein (Nutripiscis TR 36%) twice a day (9:00 am and 3:00 pm) at a feeding rate of 2.5% of biomass. Every 15 days, the animals were sampled for biometry. All fish were anesthetized by immersion in water containing diluted eugenol (80 $mg.L^{-1}$) for one minute and then measured and weighed on a precision scale (0.1 g) to evaluate the biomass gain (BG = $g.day^{-1}$), specific growth rate (SGR = $\%.day^{-1}$), feed conversion rate (FCR), and survival rate (S = %), using the following formulas:

(1) BG = (Final weight – Initial weight) / t

(2) SGR = [(ln(Final weight) – ln(Initial weight)) / t] * 100

(3) FCR = A (kg) / BG

(4) S (%) = (Final pop. / Initial pop.) * 100

Where: "t" is the duration of the experiment, "A" is the amount of feed offered in kilograms, "GB" is the biomass gain, and "pop" is the number of individuals in the population.

After each biometry, adjustments were made to the food supply according to the biomass observed in each replicate.

To obtain *E. sativa* microgreens, 60 pesticide-free seeds (± 5 seeds) were distributed in each pot placed in both hydroponic units (NFT and FRT). Each germination cycle lasted 10 days, with monitoring of seed germination and contact of the pots with the system water. No nutrient solution was added to any treatment to assess the performance of the vegetables with only the nutrients coming from the water (excrement and dissolved food scraps). At the end of each cycle, the germinated microgreens from each treatment were collected for measurement of the standard length of each pot (distance in centimeters between the stem, without the root, and the highest leaf), fresh weight (weight in grams of the microgreens from each replicate), and germination index of each replicate (ratio between the number of germinated seeds and the total number of distributed seeds). Between cycles, the hydroponic units were cleaned to remove accumulated residues and the space was readjusted for a new seeding.

2.4. Water quality and consumption

Water parameters were measured daily along the experiment. Temperature, pH (digital pH meter), and dissolved oxygen (Instrutherm MO-920 oximeter) were measured every day. Corrections were made to pH, using sodium bicarbonate ($NaHCO_3$), whenever values below six were observed, as pH values below this level can compromise bacterial nitrification in the system (Suárez-Cáceres *et al.*, 2021). Water samples were collected from each replicate weekly for analysis of nitrogen compounds ($N\text{-}NO_2$, $N\text{-}NO_3$, and NH_3), alkalinity, and orthophosphate (PO_4^{3-}) using a photometer.

Along the experiment, water additions were carried out weekly in the systems to replace the volume lost due to evaporation inside the greenhouse. These amounts were annotated to determine the water consumption demanded by the systems.

2.5. Statistical analysis

All replicate results were grouped to allow the comparison between treatments (NFT vs. FRT). For all data, the Shapiro-Wilk normality test (Shapiro & Wilk, 1965) and Bartlett's homoscedasticity test (1950) were performed. Significant differences between treatment means were verified using the *t*-test for parametric data [nitrate and orthophosphate (water quality), FCR, BG, and SGR (tambaqui performance), standard length, fresh weight, and germination index (microgreen performance)] and the Kruskal-Wallis test for non-parametric data [dissolved oxygen, pH, temperature, nitrite and ammonia (water quality), total weight and length (tambaqui performance)]. All analyzes were performed using the R statistical software (R Core Team, 2020). The results of fish and microgreen performance were presented in the format of mean and standard deviation.

2.6. Economic viability analysis

All investment was accounted to provide information regarding the construction of the entire project structure (eight experimental units) or a single farming system. Expenses were considered for building materials, inputs (feed, seeds, animals, analysis kits), water consumption (worldwide average tariff for 1 m^3 in 2022 for households that consume up to 30,000 m^3), and energy consumption. Energy consumption was considered in two ways: through investment in solar energy capture or through the monthly increase in conventional energy bill, based on the international average price of kWh (GPP, 2022). Finally, a family wage of US$ 239.37 was considered to infer the project's viability.

3. Results

3.1. Water quality and consumption

The results of all water quality variables were expressed in Table 1. Significant differences were identified between treatments in the concentrations of dissolved oxygen (DO) (NFT = 5.28 $mg.L^{-1}$ ± 1.12; FRT = 5.98 $mg.L^{-1}$ ± 1.12) and ammonia (NFT = 0.849 $mg.L^{-1}$ ± 0.187; FRT = 0.677 $mg.L^{-1}$ ± 0.181). The water temperature remained within the animals' comfort zone (NFT = 28.1 °C ± 1.72; FRT = 28.3 °C ± 1.74). Low temperatures (< 26°C) were occasionally recorded during the first four weeks, due to winter season in the region. The pH remained below neutrality for most of the cultivation (NFT = 6.15 ± 0.53; FRT = 6.28 ± 0.53), with acidifying tendencies (pH 5.3) over the weeks. On days when sudden drops in pH were observed (< 6.0), adjustments were made using sodium bicarbonate. Alkalinity also resulted in low concentrations (NFT = 11.3 $mg.L^{-1}$ ± 4.44; FRT = 10.8 $mg.L^{-1}$ ± 4.44) along the experiment.

The weekly alkalinity, nitrogen compounds, and orthophosphate concentrations was demonstrated graphically (Figure 2). Gradual adjustments to alkalinity increased significantly during the last weeks of the experiment, despite very small accumulations. Significant concentrations of un-ionized ammonia were recorded in both treatments (NFT = 0.849 $mg.L^{-1}$ ± 0.187; FRT = 0.677 $mg.L^{-1}$ ± 0.181), with the lowest concentration observed in the sixth week of farming, followed by new peaks in the last weeks of the experiment. There was low accumulation of nitrite ($N\text{-}NO_2$) in the water, with the highest peak recorded in the eighth week (~ 0.3 $mg.L^{-1}$). Similarly, nitrate ($N\text{-}NO_3$) also resulted in small accumulations (NFT = 0.293 $mg.L^{-1}$ ± 0.0041; FRT = 0.291 $mg.L^{-1}$ ± 0.028), with a decreasing tendency over the weeks. Low concentrations of orthophosphate (PO_4^{3-}) were recorded (NFT = 0.009 $mg.L^{-1}$ ± 0.0063; FRT = 0.011 $mg.L^{-1}$ ± 0.0068), suggesting interference from other factors in the availability of soluble phosphorus in the water. Naturally, all tanks began to have the presence of phytoplankton, due to the availability of light and nutrients in the water.

Weekly, approximately 60 L of water were replenished in each cultivation tank, corresponding to losses caused by evaporation inside the greenhouse. Over a month, the water consumption of an experimental unit for the baby tambaqui production was approximately 240 L. Considering the eight systems, the consumption was 480 L per week, totaling approximately 3,920 L along the experiment.

3.2. *C. macropomum* growth performance

The growth results of tambaqui were expressed in Table 2. A significantly higher growth was observed among the individuals in the NFT systems (136.38 g ± 35.67 g; 19.4 cm ± 1.78 cm) when compared to the FRT systems (116.5 g ± 24.63 g; 18.4 cm ± 1.28 cm). From the 15th day of cultivation, it was already possible to observe the difference in weight and length between the fish of each treatment (Figure 3). Both biomass gain, feed conversion rate, and specific growth rate did not show significant differences between treatments. However, both conversion values are considered high (NFT = 2.18 ± 0.63; FRT = 2.55 ± 0.61) in productive way. Both treatments did not reach the expected average value for the "baby tambaqui" category (≥ 300 g). The water quality was considered a limiting factor in the performance of the animals according to their tolerance ranges for some of the analyzed parameters (temperature fluctuations, pH, and ammonia).

3.3. *E. sativa* microgreens performance

Four complete cycles of 10 days were conducted in NFT and FRT systems, with distinct intervals between each cycle according to the necessary maintenance of the hydroponic units. In all cycles, the average fresh mass and standard length of arugula microgreens were significantly higher in NFT systems (157.38 g ± 21.74 g; 6.68 cm ± 0.17 cm) compared to FRT systems (41 g ± 6.18 g; 4.46 cm ± 0.58 cm) (Table 3). Similarly, the germination index indicated a higher percentage of germinated seeds in the tubular structure compared to the floating structure (NFT = 65.43% ± 9.91%; FRT = 34.02% ± 13.57%). Water quality was also a limiting factor in the success of germination between systems and cycles. FRT systems, at the end of each cycle, presented a layer of biofilm on the water surface of each box, regardless of the adjustments made on the structures. The NFT system demonstrated the best performance of microgreens in all evaluated scenarios.

3.4. Economic viability

For the economic feasibility analysis of developing an aquaponic system in a residential environment, the Brazilian minimum wage equivalent to US$ 239.37 in 2022 was considered, and a simulation was projected where in a family of four persons, at least one has access to the proposed salary. The cost calculations were expressed in Table 4 under two scenarios: (I) building one experimental unit and (II) building eight experimental units. Each scenario presented variation in the electricity factor, considering the initial investment in a photovoltaic system for solar energy capture or simply attributing the additional cost in dollars to the conventional energy bill based on the system's kilowatt consumption.

The investment in solar energy was US$ 737.84 to serve the eight experimental units, while the cost for a single system was estimated at US$ 460.94. On the other hand, the estimated cost via conventional electricity resulted in a monthly increase of US$ 2.08 (for one experimental unit) or US$ 16.65 (for eight experimental units) on the energy bill. The water consumption of one system led to a monthly increase of US$ 0.34 on the water bill, while for eight systems, the value was US$ 5.37/month. The acquisition of materials for aquaponic systems was US$ 114.89 for one system and US$ 708.48 for eight experimental unit, considering the use of NFT hydroponic units for microgreen farming. Additionally, variable costs with main inputs (food, *E. sativa* seeds, tambaqui juveniles, water analysis kits, and equipment replacement) were US$ 93.57 for one system and US$ 110.09 for eight experimental unit. The lowest cost was found when acquiring a single hydroponic experimental unit with conventional energy consumption, a total of US$ 229.90 for the structure assembly, with monthly payments of US$ 23.94 (10% of the salary) for approximately nine months, aiming for immediate production.

The consumption of microgreens was considered on a weekly basis, in any chosen production scenario. On the other hand, obtaining protein with a single experimental unit proved to be limited due to the long 70-day intervals in fish growout.

4. Discussion

Aquaponics can be considered an activity that demands a lot of effort from the producer while promoting a balance game between the two main productive aspects: animal and plant, which requires constant monitoring of all quality parameters established in the cultivation system. In this study, water quality was the determining factor of the results obtained. The water temperature (between 26 to 29 °C) remained within the ideal range for the growth and well-being of the fish for most of the experiment (Amanajás & Val, 2022). However, during the first weeks, there was a cold period associated with winter that caused a decrease in temperature (< 26 °C). Such a condition may have been one of the vectors of interference in the feed conversion of tambaqui (NFT = 2.18 ± 0.63; FRT = 2.55 ± 0.61), since temperatures below the comfort range of tropical fish can inhibit feeding and digestion, affecting growth (Da Costa Barroso *et al.*, 2020; De Oliveira *et al.*, 2017).

Dissolved oxygen showed differences between the two treatments, despite the same flow rate assigned to the experimental units. The difference in the structure of the hydroponic units may have been due to the water path until gravity fall into the fish tank. However, the availability of oxygen for fish and for the microgreens roots was within ideal conditions for aquaponic systems ($\geq$ 5 $mg.L^{-1}$) (Lima & Bastos, 2020; Rakocy, 2012c).

The pH, on the other hand, may have been a key indicator in the productive performance of the experimental units. The average pH, in both NFT and FRT systems, showed a tendency towards acidity after 40 days of farming. The low alkalinity of the systems (Figure 2) also contributed to the pH fluctuations, as the ideal concentrations of $CaCO_3$ for recirculation systems are between 40 to 100 $mg.L^{-1}$ (Boyd *et al.*, 2016; Hundley & Navarro, 2013). The water used in the study came from the supply unit of the region, and its low alkalinity was unable to neutralize the acidity of the cultivation tanks during replenishments, even with the corrections made with sodium bicarbonate ($NaHCO_3$), since alkalinity has a buffering effect on pH and is responsible for its stability in cultivation systems in general (Boyd *et al.*, 2016). Greenfeld *et al.* (2019) describe that controlling the ideal pH for the nitrification process is more important than the ideal pH for plants, for example.

The concentrations of ammonia along the experiment (Figure 2) showed a considerable decrease in the sixth week, indicating the activity of the biofilters. However, in the following weeks, all experimental units showed new accumulations of ammonia in the water, reaching the tolerated limit for most fish species (< 1 $mg.L^{-1}$) (Zuffo *et al.*, 2021; Quaresma *et al.*, 2020; Wei *et al.*, 2019; Rakocy, 2012c). The acidity of the pH during these periods (pH < 6.0) may have been responsible for the inactivity of the nitrifying bacteria and consequent inefficiency of the biofilters, resulting in accumulations of non-ionized ammonia (Suárez-Cáceres *et al.*, 2021).

Both nitrite ($N\text{-}NO_2$) and nitrate ($N\text{-}NO_3$) showed low concentrations along all weeks. This is an interesting result for nitrite, as concentrations above 1 $mg.L^{-1}$ are toxic to fish in general (Izel-Silva *et al.*, 2020). Concentrations of nitrate above 5 $mg.L^{-1}$ are essential in aquaponic systems, as it is the main nitrogen compound assimilated by plants for growth and is not toxic to fish (Wei *et al.*, 2019; Wongkiew *et al.*, 2017). As observed in the ammonia concentrations, much more could have been converted by the biological filters. Despite the theoretical use in the sizing of the biofilters, perhaps their practical application was not totally effective in bacterial activity.

The presence of phosphate in the water of the farming tanks, for phosphorus availability, was minimal (Figure 2), possibly due to the influences of low alkalinity and acidic pH on nutrient solubility (Boyd *et al.*, 2016; Eltez & Taskavak, 2016; Wurts & Durborow, 1992). Despite this, the microgreens of arugula germinated quickly (10 days) and without apparent signs of nutritional deficiency, such as spots, loss of color, or necrosis, indicating the assimilation of almost all phosphorus and nitrate whenever available in the water. Nitrate uptake by plant roots, for example, is more effective in waters with acidic to near-neutral pH levels (Kizak & Kapaligoz, 2019), as evidenced in the experiment. It is known that the nutritional demand of most vegetables is minimal in the germination phase since the seed provides nutrition while the roots are not fully developed (Mir *et al.*, 2017).

For *C. macropomum*, in 70 days, no mortality was observed, with individuals showing a final average weight of 136.38 g in the NFT tanks and 116.50 g in the FRT tanks, both at a growth rate of 1% per day (Table 2). These data are similar to the results found by Oliveira *et al.* (2022), who achieved a growth perfomance of tambaqui with an average weight of 50 g and, at the end of 90 days, the average final biomass was close to 150 g. The difference in performance between the NFT and FRT treatments may have been established due to the lower frequency of feed consumption observed in the FRT treatment during winter and the low temperatures recorded, also observed in the feed conversion ratio of the treatments. As weeks passed, variations in pH and ammonia concentrations may also have been the main responsible factors for differences in animal performance between treatments in terms of growth (Figure 3). Tambaqui can tolerate ammonia concentrations up to 0.46 $mg.L^{-1}$ (Ferreira *et al.*, 2021; Rodrigues, 2014), while the average concentrations of the treatments were twice the tolerated level.

The stocking density (10 juveniles/0.2 m^3) may have also been a limiting factor to growth, as high densities compromise water quality (Surnar *et al.*, 2015). The relation between ammonia and high density are factors that directly affect fish growth. Sousa *et al.* (2016), when evaluating different densities for tambaqui juvenile farming in an intensive system, identified that at high densities, tambaqui can reach a higher ammonia excretion rate (93.7%, 0.35 $mg.L^{-1}$/day), related to stress and consequently making the fish more sensitive to this physicochemical variation. Oliveira *et al.* (2022) conducted tests with different densities in the growout of tambaqui juveniles in aquaponics and obtained the best performance at a density of 20 animals/m^3. From this perspective, the density adjusted for the project dimensions should be up to four tambaquis per tank (0.2 m^3).

The experiment was conducted in small volumes aiming for aquaponic production in small spaces. A reduction in the number of tambaquis cultivated per tank can be an alternative to improve water quality and fish comfort, which can also favor growth (Signor *et al.*, 2020).

For *E. sativa* microgreens, one of the hydroponic models proved to be more effective (Table 3). NFT units showed significantly greater growth, both in weight and length, than FRT units, and the gram production of each cycle was four times higher in the tubular channels. Similarly, the germination rate in NFT was twice as high as in FRT (more than half of the seeds germinated in each cycle in NFT). Two observed factors may justify this difference: (I) the water flow in the tubular channels allowed a greater renewal of the water in contact with the seed pots than in the floating structure boxes, which always maintained a fixed volume concentrated with slower renewal; and (II) in each cycle, a thin biofilm layer formed in the water surface of FRT boxes, whose phytoplankton communities may have been responsible for sequestering part of the nutrients in the water (nitrogen, phosphorus, and carbon) for their growth (Kotzen *et al.*, 2019).

Based on the investment data projected in this study (Table 4), the lowest production cost, considering a monthly wage of US$ 239.37, was the acquisition of materials for building a system (US$ 229.90) with conventional electricity supply (US$ 2.08 per month added to the electricity bill). However, obtaining a single system would not attend the purpose of replacing the food supply of a family in a food insecurity condition. On one hand, the supply of microgreens remains constant due to their short production cycles, but on the other hand, the farming cycles of baby tambaqui have windows of 70 days until they are ready for consumption.

It is known that consuming 100 g of fish can provide between 18 to 20 g of protein, approximately one-third of the recommended average protein intake (Ariño *et al.*, 2013). In the experiment, within 70 days, the average weight of tambaqui was above this recommendation. However, considering the need to decrease the tank density, fewer fish would be available for consumption. Considering a family of four, it would only be possible to consume fish (± 130 g) once a week and wait for a new farming to reach this average production. In the end, this investment, as planned in the experiment, tends to be costly for low-income populations and does not attend the demand for food in order to combat food insecurity.

The literature is still incipient regarding subsistence aquaponics. Some studies suggest the commercialization of a percentage of the cultivated fish and plants but indicate that there may be some resistance in buying the animals since the fish produced in aquaponics would need to be sold above the price of conventional aquaculture to compensate for the expenses (Sunny *et al.*, 2019; Engle, 2016). In Europe, only 17% of people have shown willingness to pay more for aquaponic fish (Araújo *et al.*, 2021). Rizal *et al.* (2018) remained optimistic by indicating a quick return on investment from a short value chain between the producer and direct sales to consumers, restaurants, and supermarkets. In some regions of Africa, alternatives to reducing construction costs lie in the imported purchase of materials and the substitution of artificial food with insects (Obirikorang *et al.*, 2021). Overall, commercialization seems to be the easiest path to economically developing home aquaponics but deviates from the purpose of family subsistence. Some research shows that most people who engage in aquaponic farming treat the activity only as a hobby and have other primary sources of income (Colt *et al.*, 2022; Love *et al.*, 2014a).

A viable alternative may lie in initial subsidies through public policies. The inclusion of urban small-scale producers in programs that subsidize small-scale rural producers is a possible solution. Greenfeld *et al.* (2019) categorize aquaponics in terms of cost-benefit. One category describes the activity as "beneficial to society, but with low profitability" and advocates for public intervention through the participation of politicians who receive knowledge about aquaponics and promote actions to make it attractive for producers.

Silva & Van Passel (2020) suggest the inclusion of aquaponics in the criteria for financing systems, such as Inovagro, a Brazilian program of the National Development Bank (BNDES), responsible for promoting sustainable projects in rural areas. Thus, the producer receives the necessary amount for the construction of the number of systems deemed necessary to attend their demand and has a repayment period of up to ten years, being able to pay off their debt with greater flexibility.

In this sense, the implementation of tambaqui aquaponics and microgreens of arugula in urban areas is still not a viable activity. New studies are needed to strengthen the understanding of the activity's execution and optimize quality control, as well as to allow the projection of feasible alternatives for low-income populations.

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4- Considerações finais

O atual projeto permitiu explorar novas vertentes na produção por aquaponia, desde o cultivo de tambaquis em um modelo atual ("baby fish") até a produção de rúculas em estágio inicial de germinação (microverdes). Ambas as práticas configuram inovações científicas e tecnológicas a serem otimizadas com o tempo. No mais, o estudo de viabilidade confirmou que a aquaponia de subsistência é uma atividade com muitos entraves a serem vencidos antes de poder ser considerada viável.

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ANEXOS

Figure 1. Structure of the aquaponic systems developed in the greenhouse. On the right is the NFT (*Nutrient Film Technique*) hydroponic structure, and on the left is the FRT (*Floating Raft Technology*) structure.

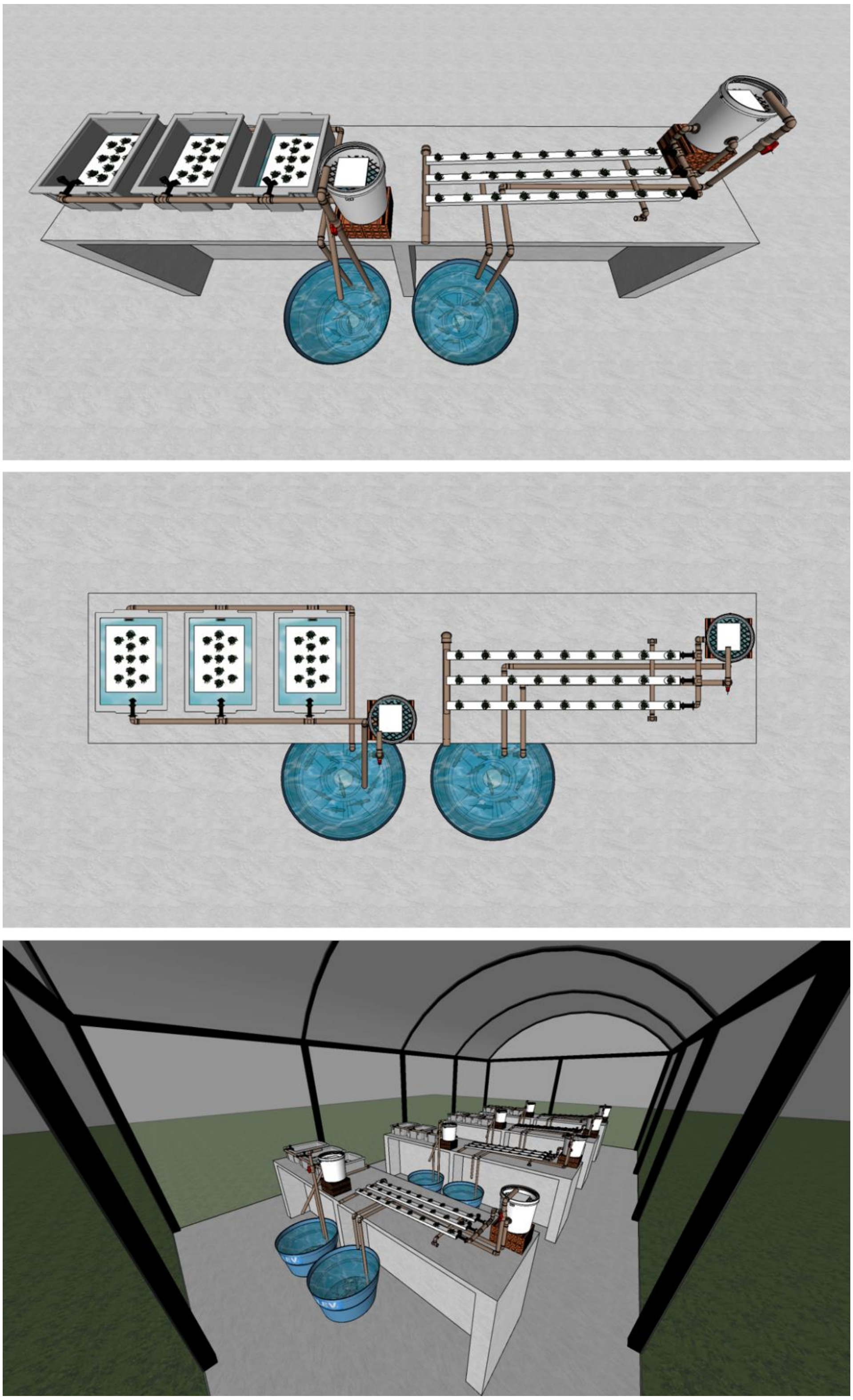

Figure 2. Graphs of water parameter behavior in NFT and FRT treatments over the 10 weeks of farming: (A) nitrate, (B) nitrite, (C) ammonia, (D) orthophosphate, and (E) alkalinity.

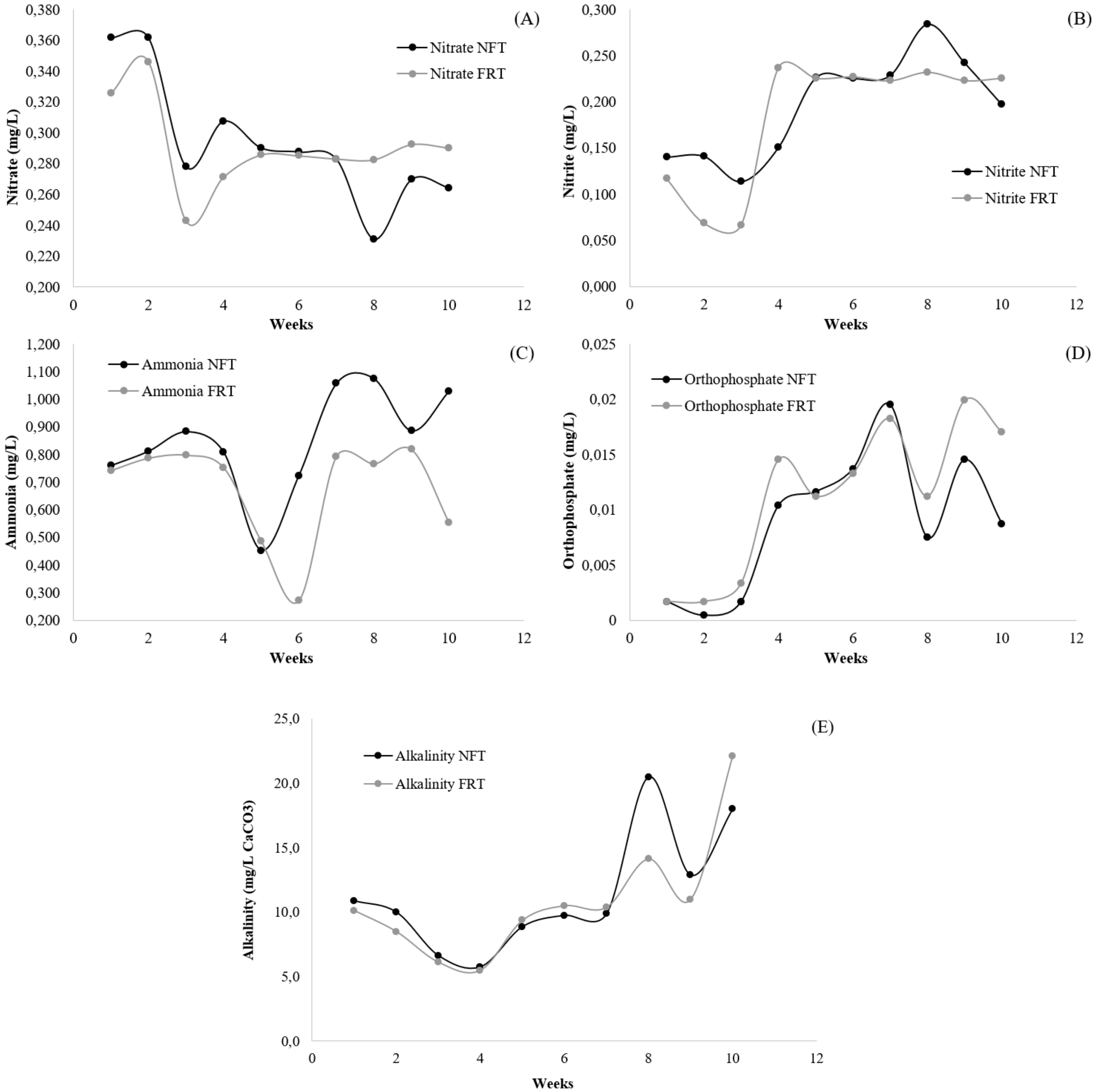

Figure 3. Means of weight and total length of *C. macropomum* in the tanks of NFT and FRT treatments during the biometric measurements taken every two weeks over 70 days. Statistical differences shown with (*).

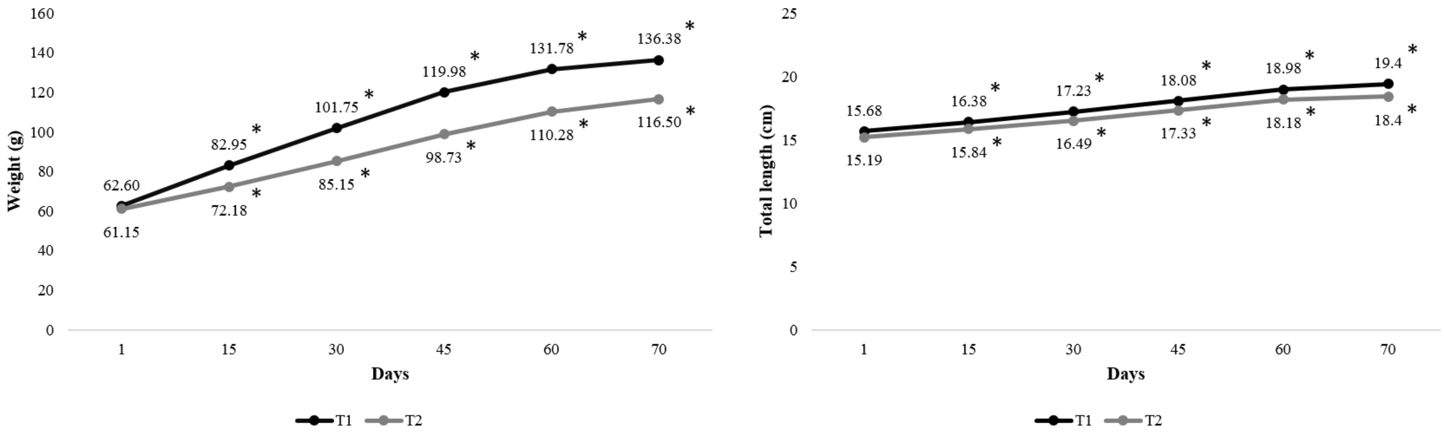

Table 1. Means of water quality parameters evaluated in NFT and FRT treatments along the experiment.

	NFT	**FRT**
Dissolved oxygen (mg.L^{-1})	5.28 ± 1.12^{a}	5.98 ± 1.12^{b}
pH	6.38 ± 0.5	6.31 ± 0.48
Temperature (°C)	27.9 ± 1.23	28.2 ± 1.47
Alkalinity (mg.L^{-1} $CaCO_3$)	11.31 ± 4.68	10.8 ± 4.68
Ammonia (mg.L^{-1} NH_3)	0.849 ± 0.187^{a}	0.677 ± 0.181^{b}
Nitrite (mg.L^{-1} N-NO_2)	0.195 ± 0.055	0.185 ± 0.07
Nitrate (mg.L^{-1} N-NO_3)	0.294 ± 0.0412	0.291 ± 0.028
Orthophosphate (mg.L^{-1} PO_4^{3-})	0.009 ± 0.0063	0.011 ± 0.0068

Different letters indicate significant differences between treatments by *t*-test or Kruskal-Wallis test ($p < 0.05$).

Table 2. Growth performance of tambaqui (*C. macropomum*) in the tanks of NFT and FRT aquaponic systems.

	NFT	FRT
Survival rate (%)	100	100
Initial weight (g)	62.6 ± 6.46	61.15 ± 9.94
Final weight (g)	136.38 ± 35.67[a]	116.50 ± 24.63[b]
Initial length (cm)	15.68 ± 0.43	15.19 ± 0.77
Final length (cm)	19.4 ± 1.78[a]	18.4 ± 1.28[b]
Biomass gain (g.day^{-1})	1.065 ± 0.27	0.822 ± 0.15
Specific growth rate (%.day^{-1})	1.06 ± 0.44	0.89 ± 0.21
Feed conversion rate	2.18 ± 0.63	2.55 ± 0.61

Different letters indicate significant differences between treatments by *t*-test or Kruskal-Wallis test ($p < 0.05$).

Table 3. Performance of arugula (*E. sativa*) microgreens in each production cycle in NFT and FRT units, and total average value.

	1st cycle		2nd cycle		3rd cycle		4th cycle	
	NFT	**FRT**	**NFT**	**FRT**	**NFT**	**FRT**	**NFT**	**FRT**
Standard length (cm)	6.51 ± 0.62^{a}	4.67 ± 0.81^{b}	6.61 ± 0.86^{a}	5.25 ± 0.84^{b}	6.96 ± 0.88^{a}	4.21 ± 0.66^{b}	6.62 ± 1.14^{a}	3.69 ± 0.64^{b}
Fresh weight (g)	187.75 ± 7.08^{a}	51 ± 11.55^{b}	155 ± 31.06^{a}	40.75 ± 11.95^{b}	160.25 ± 19.66^{a}	37.75 ± 8.93^{b}	126.5 ± 34.5^{a}	34.5 ± 14.15^{b}
Germination index (%)					68.09 ± 9.49^{a}	28.84 ± 8.15^{b}	60.5 ± 8.59^{a}	33.34 ± 15.39^{b}

	Mean	
	NFT	**FRT**
Standard length (cm)	6.68 ± 0.17^{a}	4.46 ± 0.58^{b}
Fresh weight (g)	157.38 ± 21.74^{a}	41 ± 6.18^{b}
Germination index (%)	65.43 ± 9.91^{a}	34.02 ± 13.57^{b}

Different letters indicate significant differences between treatments by *t*-test or Kruskal-Wallis test ($p < 0.05$).

Table 4. Financial data on investments and project execution costs for economic viability analysis.

		Value - 01 system (US$)	Value - 08 systems (US$)
Electricity (*solar energy – one-time initial investment*)		**Value - 01 system (US$)**	**Value - 08 systems (US$)**
Solar panel (*400W mono*)		214.95	214.95
Stationary battery (*150 A/h*)		188.08	188.08
Submersible pump (*800 L/h - 20W*)		**19.36**	**154.88**
Charge controller (*30A*)		27.50	27.50
Electrical wiring (*1.5 e 16 mm cables*)		11.05	152.43
	Total:	**460.94**	**737.84**
Electricity (*conventional electrical energy*)		**Value - 01 system (US$)**	**Value - 08 systems (US$)**
Energy consumption (*1 kWh = US$ 0.16; 01 pump = 0.02 kWh*) *(world average price, 2022)*	**Total added to the monthly electricity bill:**	**2.08**	**16.65**
Water		**Value - 01 system (US$)**	**Value - 08 systems (US$)**
Water consumption (*m^3 = US$ 1.37*)	**Total added to the monthly water bill:**	0.34	5.37
Farming systems		**Value - 01 system (US$)**	**Value - 08 systems (US$)**
Tanks (*water tanks*)		46.53	372.20
Piping		9.51	76.10
Piping connections		21.50	171.95
Hydroponic units (*NFT*)		16.96	67.83
Substrate (*expanded clay pebbles*)		20.39	20.39
	Total:	**114.89**	**708.47**
Inputs/Other costs		**Value - 01 system (US$)**	**Value - 08 systems (US$)**
Feed (*36% PB 4 mm*)		26.43	26.43
Seeds (*E. sativa*)		5.43	10.86
Juveniles (*C. macropomum*)		1.58	12.67
Water analysis kits		35.75	35.75
Equipment replacement (pumps, piping)		24.38	24.38
	Total:	**93.57**	**110.09**
TOTAL		**Value - 01 system (US$)**	**Value - 08 systems (US$)**
With electricity from solar energy		669.40	1556.4
With electricity from conventional energy		**229.90**	990.09