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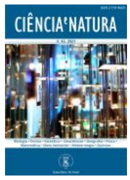

ISSN 2179-460X
Acesso aberto

Ci. e Nat., Santa Maria, v. 43, e95 2021 • https://doi.org/10.5902/2179460X63222
Submitted: 23/11/2020 • Approved: 08/09/2021 • Published: 31/12/ 2021

Environment

Growth of fingerlings in different stocking densities in tropical aquaponic system of basil production

Crescimento de alevinos em diferentes densidades de estocagem em sistema aquapônico tropical de produção de manjericão

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ABSTRACT

Aquaponics proposes a synergistic relationship between aquaculture and hydroponic production, with the principle of imitating nature, favoring nutrient cycling and water recirculation. The aim of this work was to evaluate fish and vegetable production, as well as water quality in the constituents of small-scale tropical aquaponic systems. The fish systems consisted of tanks with $3m^3$ of volume and different densities, T1 (72 $fish^{-3}$); T2 (144 $fish^{-3}$); T3 (216 $fish^{-3}$), populated with Nile tilapia (Oreochromis niloticus), with filters for the nitrification process. Plant production systems have 12 channels (6m long) of PCV per fish tank, filled with gravel and spacing 15 cm per plant, basil (Ocimum basilicum). The experiment lasted 45 days, being replicated. For the analysis of fish and plant performance, biometrics were performed every 15 days. The results demonstrate that animal growth, evaluated by weight gain, total length and standard length of the treatments did not show statistically significant differences, as well as for plant parameters, but in all treatments both showed satisfactory growth. The water quality parameters remained as recommended for aquaponics. Aquaponic systems have demonstrated their viability in animal and plant production in the tropics.

Keywords: Aquaponics, nutrient cycling, water recirculation, fish production.

RESUMO

A aquaponia propõe uma relação sinérgica entre as produções aquícolas e hidropônicas tendo como princípio imitar a natureza favorecendo a ciclagem de nutrientes e a recirculação de água. O trabalho teve como objetivo avaliar as produções piscícola e vegetal, além da qualidade de água nos constituintes de sistemas aquapônicos tropicais de pequena escala. Os sistemas piscícolas consistiram em tanques de 3m³ de volumetria e diferentes densidades, T1 (72 peixes^{-3}); T2 (144 peixes^{-3}); T3 (216 peixes^{-3}), povoados com tilápia do Nilo (*Oreochromis niloticus*), com filtros para processo de nitrificação. Os sistemas de produção vegetal possuem 12 canaletas (6m de extensão) de PCV por tanque piscícola, preenchidos de cascalho e espaçamento de 15 cm por planta, majericão (*Ocimum basilicum*). O experimento teve duração de 45 dias, sendo replicado. Para a análise das performances piscícola e vegetal foram realizadas biometrias a cada 15 dias. Os resultados demonstram que o crescimento animal, avaliado pelo ganho de peso, comprimento total e comprimento padrão dos tratamentos não apresentaram diferenças estatísticas significativas, assim como para os parâmetros vegetais, porém em todos os tratamentos ambos apresentaram crescimento satisfatório. Os parâmetros de qualidade da água se mantiveram como preconizado para aquaponia. Os sistemas aquapônicos demonstraram sua viabilidade na produção animal e vegetal nos trópicos.

Palavras-chave: Aquaponia, ciclagem de nutrientes, recirculação de água, produção piscícola.

1 INTRODUCTION

World demand for water has increased due to population growth, economic development and changing consumption patterns, among other factors, and will continue to increase significantly over the next two decades (HUNDLEY AND NAVARRO, 2013; UNESCO, 2018). There is a general consensus that environmental, social and economic challenges drive the need for new and improved solutions for food production and consumption systems, the food systems (KONIG et al., 2018).

Production systems that minimize impacts on the environment are the scientific-technological basis for a sustainable development project and aquaponics, as a low-water consumption and nutrient reuse system, can help promote agroecological principles and use of social and appropriate technologies (CORRÊA et al., 2016). Aquaponics is the process of growing aquatic organisms and plants symbiotically in one system or several subsystems (LENNARD AND LEONARD 2006; MONSEES et al. 2017; YEP AND

ZHENG 2019; GODDEK AND KEESMAN, 2020), the cycle of water and nutrients improves the efficiency of water use (LOVE et al., 2014), carry out the reuse of aquaculture wastewater (ENDUT et al., 2011), and avoid the environmental pollution caused by traditional fisheries (HAO et al, 2020), which may also reduce consumption 90% of water, compared to conventional systems, promoting the full reuse of the effluent generated within the system itself (CARNEIRO et al., 2015).

Aquaponics is an alternative for the production of food in a way that is less impactful on the environment, through characteristics that refer to sustainability, such as the implementation of small family systems and the recycling of water resources used (DIVER, 2006; RAKOCY et al., 2006; LOVE et al., 2015). This integration allows plants to use nutrients from fish farming water, improving water quality, which can be reused in fish production (HUNDLEY et al., 2013).

Aquaponics is applied by methods developed by the hydroponic industry and influenced by work from the 1970s by aquaculture researchers who experimented with raising fish in terrestrial ponds with continuously recycled water and by the sustainable agriculture movement (LOVE et al., 2014). According to Somerville et al. (2014), a classic aquaponic system consists of three main units: aquaculture unit, which comprises fish ponds; filtering system, comprising sludge removal devices (eg sedimenter) and optional biofiltration (eg drip filter); and a hydroponic component for plants, which commonly occurs in Deep Water Culture - DWC, Nutrient Film Technique - NFT, Media Bed Technique - MBT or in continuous flow tables and drip systems. The fish breeding unit can be operated with low stocking densities or high densities in single tanks, and also by combining different aquatic species. Plant cultivation can also range from a few plants to intensive hydroponic production systems (PALM et al., 2018).

Currently, further refinements in the technique are being promoted by university researchers seeking to establish aquaponics as a viable agricultural sector (LOVE et al., 2014). Junge et al. (2017), suggest that the advancement of aquaponic systems should develop in at least two directions: one through low technologies (in developing and hobby countries) and the other through high technologies (in developed countries and with professional and commercial actors).

According to a study by Love et al. (2015), 71% of commercial aquaponic systems analyzed in a survey were designed and implemented by the producers themselves, while 29% were designed by consultants or purchased. Also, nearly 80% of commercial-scale aquaponics ventures are located in the United States, and 93% of aquaponiculists have completed high school. In a survey for aquaponics on the European continent, Villarroel et al. (2016) found 68 aquaponic actors distributed in 21 European countries, 75% involved in research activities and 30.8% in production and only 11.8% of respondents sold fish or plants in the last 12 months, indicating that the production of aquaponics and marketing is still a minor activity among European actors and technology is still in its infancy, formed mainly by research actors (KONIG et al., 2018).

Although aquaponics addresses issues of food safety and sustainability, its operation can be challenging because constant monitoring of aquaponics facilities is necessary for the healthy growth of fish and plants (KYAW & NG, 2017). A successful combination of hydroponics with an aquaculture system requires high levels of knowledge and skill that are not necessarily available to all aquaponic practitioners and if aquaponics is to become a more widespread commercially viable enterprise and be capable of delivering its environmental benefits, its promotion must consider the importance of prior knowledge held by entrepreneurs entering aquaponics (GREENFELD et al., 2020).

While several aquaponic systems are being implemented and operated across the globe, but mainly in developed countries, systems implemented in tropical regions can help in the provision of new data and new proposals for the development of the production technique. Tropical aquaponics can influence the adoption of measures that are less harmful to the environment with regard to the production of fish and vegetables, leveraging sustainability in all its pillars, environmental, social and economic, making scientific analyzes of these systems essential.

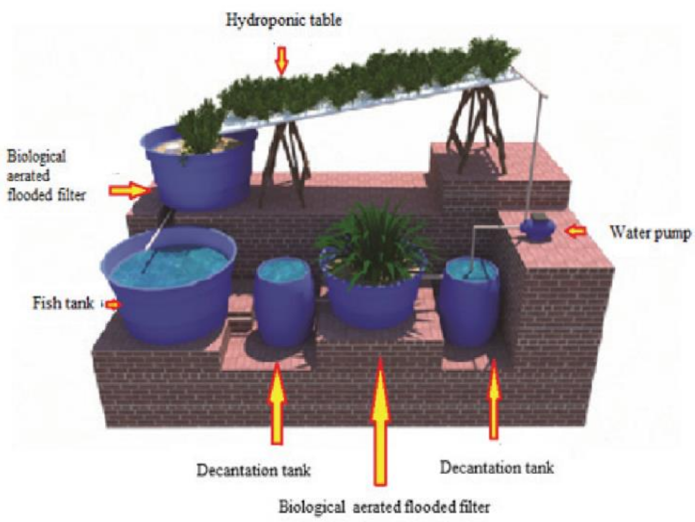
The aim of the present study was to evaluate the effect in aquaponic systems in identical pipes of different initial densities of Nile tilapia fingerlings (*Oreochromis niloticus*) on water quality, fish growth and basil (*Ocimum basilicum* L.) production. As experimental hypotheses they considered that H^0: fish density may not influence the growth of fish and plants and, in the hypothesis, H^1: with increasing fish density, animal growth will present lower values, while plant growth will be higher, H^2: with an increase in fish population density, there will be greater animal growth and less plant growth.

2 MATERIAL AND METHODS

The experiment was carried out on the Pine Tree farm (Brasília, DF, Brazil; 15º52'31.36"S, 47º48'01.28"W; altitude 1023m), in two periods, in November 2014 and March 2015, each one lasting 45 days, during the summer. The experiment was carried out in a completely randomized design in a 3x2 factorial scheme, comprising three different stocking densities of tilapia fingerlings per cubic meter, T1: 72-3, T2: 144-3 and T3: 216-3 and two replications for each treatment, Block I and Block II.

Treatments were carried out simultaneously in the same green house using three aquaponic growing systems in identical pipes (Figure 1), each consisting of five containers interconnected by polyvinyl chloride (PVC) tubing. The water from an aquarium of 3000L volume (1721cm Ø x 1124cm deep) flows through a Ø 100mm tube to a 240L settling tank, which was sequentially connected by a Ø 60mm tube to a sanded biological filter (BAFF) in a 500L water tank, populated with the papyrus sedge (*Cyperus papyrus*) and the white ginger lily (*Hedychium coronarium*).

Figure 1. Sketch of the aquaponic system used.



Source: Adapted from HUNDLEY et al., 2018.

The BAFF outlet passes through a 32 mm pipe in a reservoir equipped with a pump (® Group Boyu, Raoping, Guangdong, China) with a maximum horizontal flow of 2400 L h^{-1} and actual flow rate of 1600 L h^{-1} at lift height of 1.5 m used in the experimental setup. The water from the reservoir is distributed on the hydroponics table through a Ø 25 mm tube with perforations for 12 PVC gutters (each 6 m long) spaced 15 cm apart and filled with gravel consisting of 4 to 64 mineral fragments and mm-diameter rocks (pebbles, according to the Wentworth scale), in order to maintain the availability of nutrients for the plants and assist in their support. Aeration was constant by a 0.5 hp pump (Boyu® Group).

Water sampling was carried out through a faucet located at a collection point in the fish tanks. A total of 2,592 Nile tilapia fingerlings (Aquabel Company®) were used in the experiment, 1,296 with an initial average weight of 0.68g in Block I and 1,296 with an initial weight of 0.56g in Block II. The fish were fed with isoprotein diets containing 42% crude protein (3400 kcal kg^{-1}) at a daily rate of 5% of body weight. The food price was updated every 15 days.

Plant production consisted of fifty standardized seedlings of basil, Ocimum basilicum, for each treatment, with average initial height in Block I of 12.14 ± 1.8; 11.55 ± 3.4; 7.78 ± 3.6 cm (T1, T2 and T3, respectively), and in Block II 6.7 ± 1.8; 5.32 ± 1.2; 7.27 ± 2.4 cm (T1, T2 and T3, respectively), and initial weight in Block I of 1; 1.1; 1.2g (T1, T2 and T3, respectively) and 0.8 in Block II; 1.6; 1.1g (T1, T2 and T3, respectively). The seedlings were planted with a spacing of 10cm in the hydroponic gutters, at a density of 70plants/m^2 and, at planting, an average portion of 4 cm of each seedling remained inside the gutter.

Biometric measurements, weight (g), standard and total length (cm) of 50 fish for each treatment were performed at the beginning of the experiment and every 15 days, totaling four biometrics for each treatment. For plant biometrics, initial and final biometrics of 20 individuals of each treatment were performed. In the weight measurement, the total fresh biomass for each treatment was considered, using a Toledo® digital scale

(São Bernardo do Campo, Paraná State, Brazil) and the lengths were measured using a measuring tape.

The physicochemical water quality data were divided into initial, constituted by the first two weeks, during, fourth and fifth weeks, and final, sixth week and the final week. Water temperatures were recorded daily, in the early morning and late afternoon, using a probe (Hanna® - HI 9813-6), the level of Dissolved Oxygen (DO) in fish water was monitored weekly with the aid of an oximeter (Alfakit® – AT – 160) and the pH of the water was checked weekly using a pH meter probe (Hanna® - HI 9813-6).

2.1 Statistical Analysis

The data obtained were worked using ANOVA One-way analysis for the parameters of water quality, weight and height of plants, and analyzes of weight and standard and total lengths of fish, in order to verify statistical differences between treatments and between Blocks, using the statistical program MaxStat® Lite Version 3.60. Factorial ANOVA analyzes of the similar treatments of each Block were also performed and graphs were presented for better visualization of the differences using the statistical program Statistica® Version 10 (StatSoft). The level of statistical significance in both analyzes was set at 5%.

3 RESULTS AND DISCUSSION

3.1 Water Quality

The two most important parameters for balance the ecosystem of three groups of organisms (fish, plants, and bacteria) are pH and temperature (DESWATI et al., 2020). High or low pH values are signs of ammonia pollution in aquaculture ponds because if the pH is high then $NH4^+$ will react with OH^- and turn into ammonia (NH3) which is harmful to the fish being cultivated, if ammonia is present in an amount many can cause gill irritation and respiratory disorders that can cause death in fish (DESWATI et al., 2019).

The average water temperatures of the aquaponic systems recorded during the entire experimental period were 25.4 ± 2.5 and 22.3 ± 1.8 °C, for Blocks I and II, respectively, not showing statistically significant differences. The temperatures inside the greenhouse were 23.7 ± 4.2 and 23.6 ± 4.3 ºC for Blocks I and II, respectively, also showing no differences.

The pH did not show statistically significant differences between treatments in the Blocks (Table 1), as well as in the junction of Blocks per treatment (Table 2), showing a slight tendency to acidification throughout the experiment (Figure 2) and to neutralization if we consider the treatments at the junction of the Blocks (Figures 3 to 5).

The results obtained for the DO in aquaponics systems, (Table 1) demonstrate statistical differences between treatments, and the levels in all treatments tended to decrease throughout the experiment (Figures 6 to 9). The lowest fish stocking density T1, showed higher concentration results in both Blocks and in the joint analysis of the Blocks showed the same situation. In the higher densities, T2 and T3, during Block I the DO levels had no significant differences, unlike Block II, where T3 presented a higher level than the intermediate density, showing statistical difference.

Table 1: Values of means and standard deviation for Dissolved Oxygen (mg L^{-1}) and pH for the different treatments and between Blocks I and II, in the 45 days of the experiment.

	Block I		**Block II**	
Treatment (fish/m³)	Dissolved Oxygen (mg L^{-1})	pH	Dissolved Oxygen (mg L^{-1})	pH
T2 (144)	3.6 ± 1.5 ^{ab}	6.8 ± 0.2 ^{a}	3.2 ± 0.9 ^{b}	6.9 ±0.1 ^{a}
T3 (216)	2.0 ± 0.5 ^{b}	7.0 ± 0.1 ^{a}	4.9 ± 0.8 ^{a}	6.9 ± 0.1 ^{a}

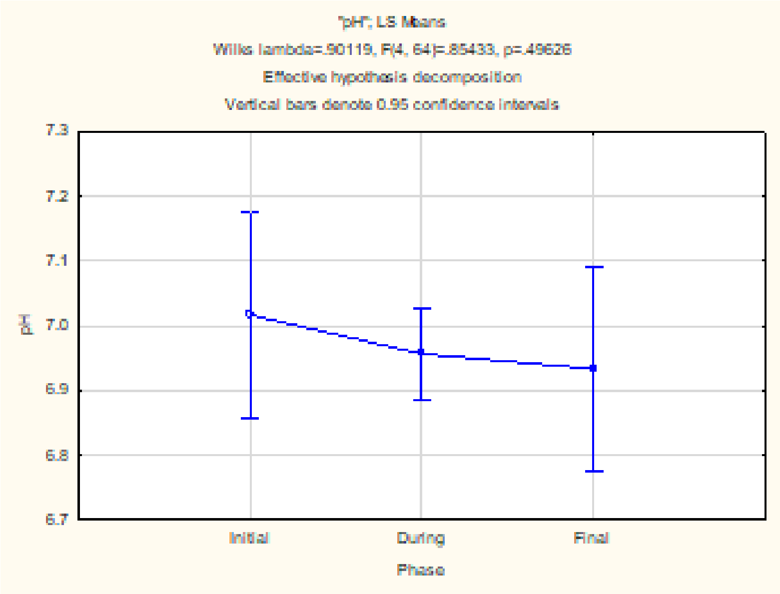
The different letters between the lines of each column represent the statistical differences according to analysis of variance (One-way ANOVA) and Tukey test, at a significance level of 95%.

Table 2. Values of means and standard deviation for Dissolved Oxygen (mg L^{-1}) and pH for the different treatments in the 45 days of the experiment.

Treatment (fish/m³)	**Dissolved Oxygen (mg L^{-1})**	**pH**
T1 (72)	5.0 ± 0.7 ^{a}	7.0 ± 0.14 ^{a}
T2 (144)	3.4 ± 0.2 ^{a}	6.8 ± 0.07 ^{a}
T3 (216)	3.4 ± 2.0 ^{a}	6.9 ± 0.07 ^{a}

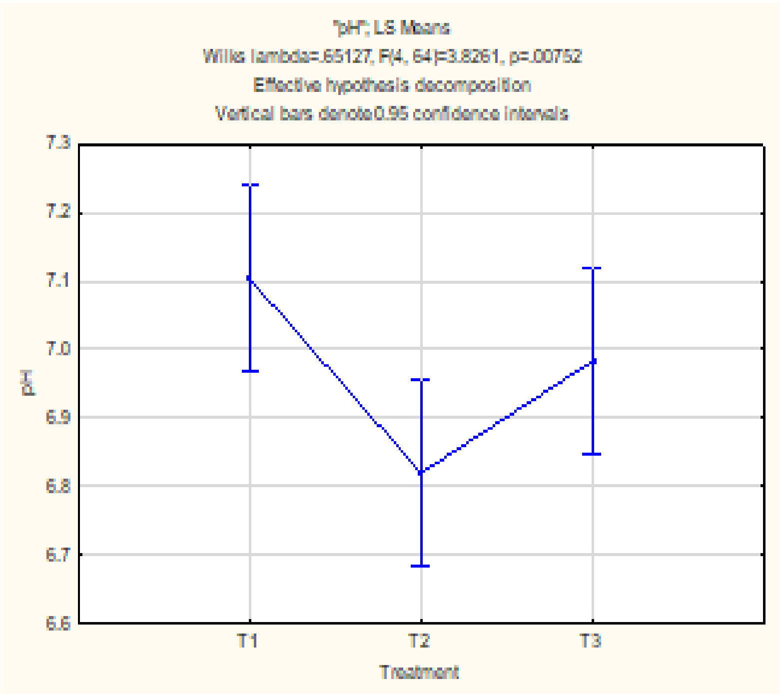
The different letters between the lines of each column represent the statistical differences according to analysis of variance (One-way ANOVA) and Tukey test, at a significance level of 95%.

Figure 2. Graph representing the pH during the phases of the experiment.



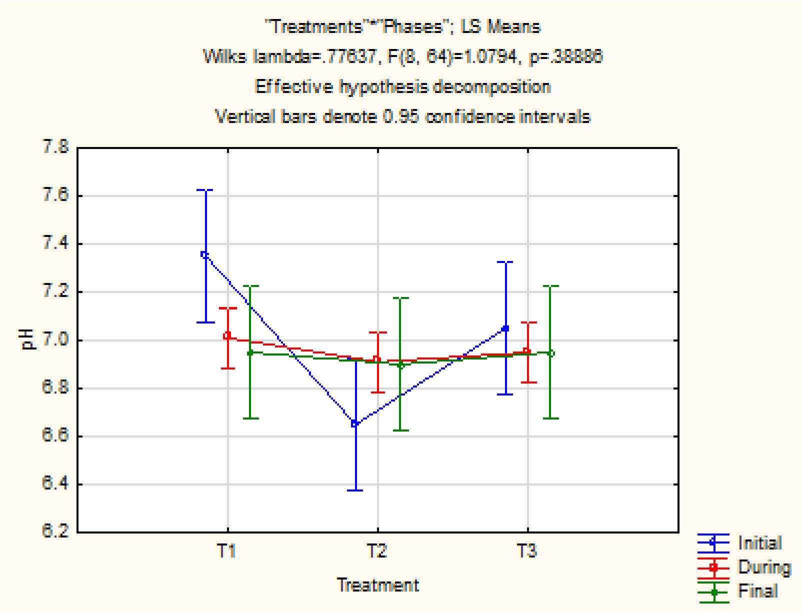
Source: Author's gallery.

Figure 3. Graph representing the average pH per treatment.



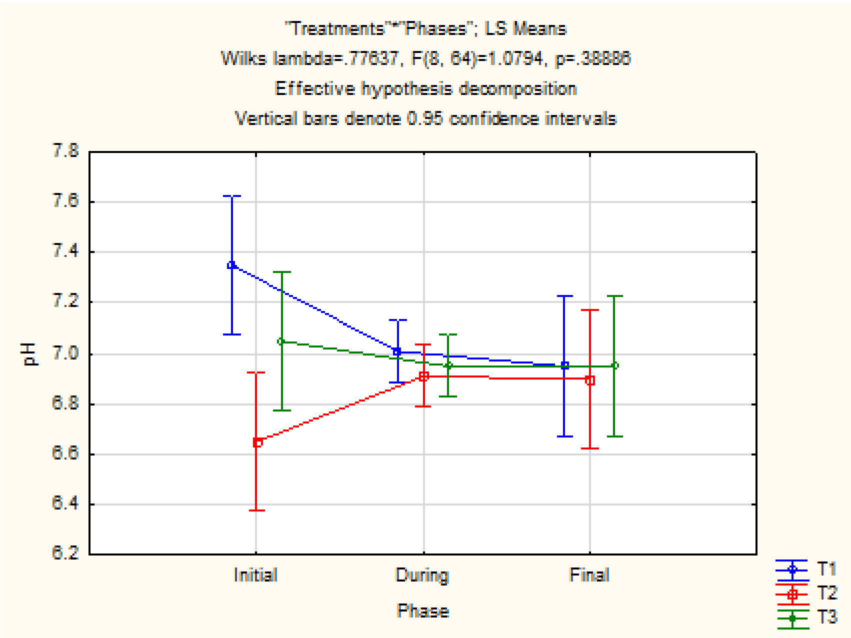
Source: Author's gallery.

Figure 4. Graph representing the pH of each treatment in the two Blocks during the phases of the experiment.



Source: Author's gallery.

Figure 5. Graph representing the pH during the phases of the experiment by treatment.



Source: Author's gallery.

Figure 6. Graph representing the concentration of DO (mg/L) during the phases of the experiment.

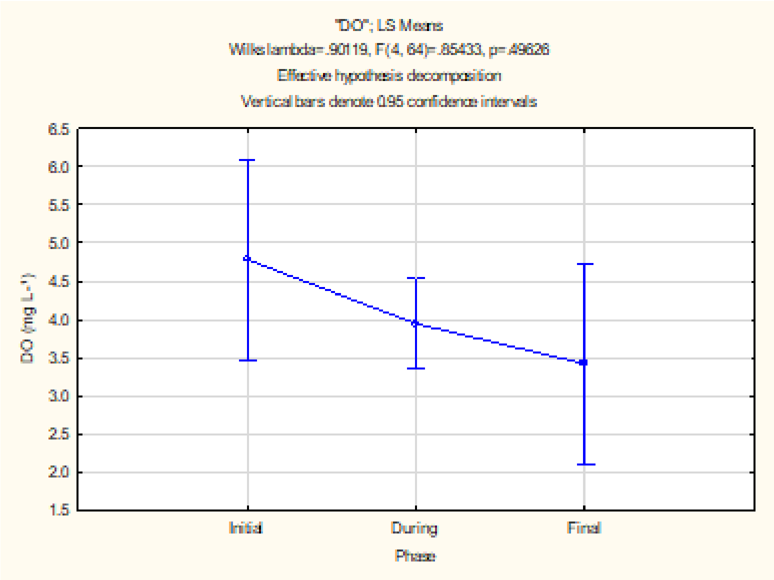


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Figure 7. Graph representing the mean concentration of DO (mg/L) per treatment.

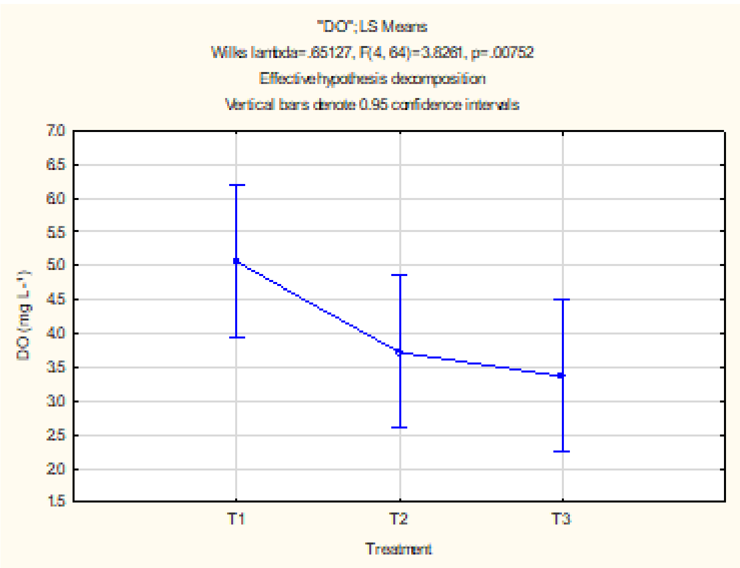

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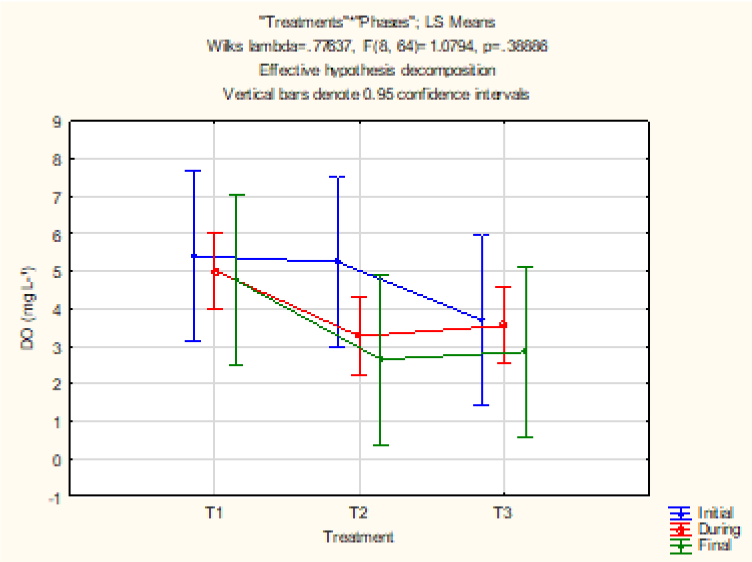
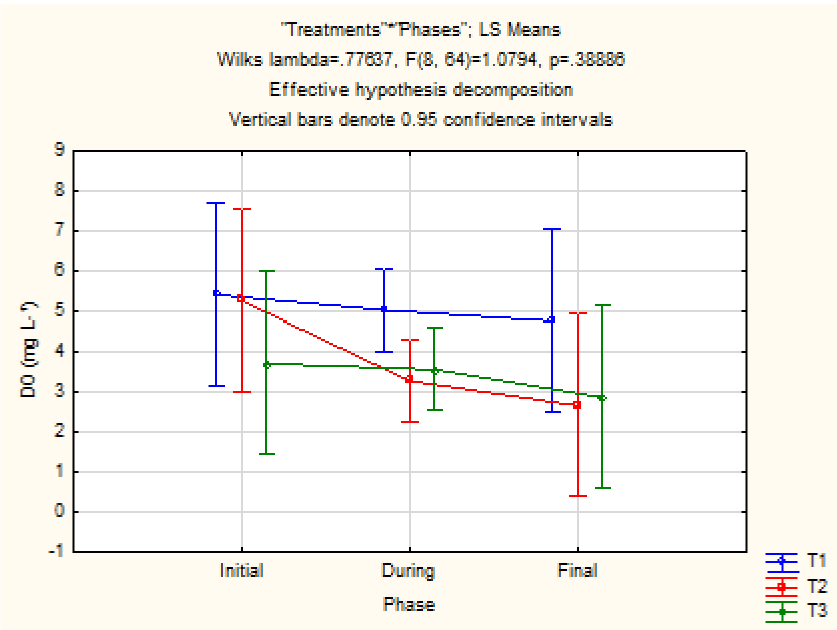
Figure 8. Graph representing the concentration of DO (mg/L) per treatment during the phases.



Source: Author's gallery.

Figure 9. Graph representing the concentration of DO (mg/L) during the phases of the experiment.



Source: Author's gallery.

The values found for the water quality parameters are in line with those recommended by Faria et al. (2013), which determines optimal values for fish production. The physical-chemical parameters of water, temperature, dissolved oxygen concentration and pH were within the optimal range for aquaponic systems as recommended by Somerville et al. (2014) and Carneiro et al. (2015).

The DO, which is one of the most important parameters for animal welfare in fish production, was established on average from 5 to 2 mg L-1, the same range indicated by Kubitza (2011) for Nile tilapia production. Furthermore, it was observed that in Block I the DO parameter was inversely proportional to the increase in density, while in Block II the highest values referred to the highest and lowest density, having a low DO value in the intermediate density. Despite not having presented statistical differences between T1 and T3 in Block II, the DO parameter tends to be more consumed in higher densities and therefore has lower values.

The pH, which is also an important parameter to assess in an aquaponic production, with values in the range recommended by the established literature for fish production, from 6.5 to 7.5 (Kubitza, 2011), showing no statistical differences between the treatments. With regard to aquaponics, the indices are in line with those found by Estim et al. (2019).

3.2 Plants

The results of plant biometrics obtained in the experiment (Table 3) demonstrate that in all treatments the plants grew satisfactorily during the period (Figures 10 and 11), showing no statistically significant differences between treatments, as well as in the joint analysis between the Blocks by treatment (Table 4).

Table 3. Mean and standard deviation values for the Initial and Final Length (cm) of plants in the different treatments and between Blocks I and II.

	Block I		**Block II**	
Treatment (fish/m³)	Average Initial Lenght (cm)	Average Final Length (cm)	Average Initial Lenght (cm)	Average Final Length (cm)
T1 (72)	12.14 ± 1.85 [a]	33.27 ± 8.66 [a]	6.70 ± 1.81 [a]	27.02 ± 7.13 [a]
T2 (144)	11.55 ± 3.45 [a]	41.52 ± 4.26 [a]	5.32 ± 1.22 [a]	31.63 ± 5.35 [a]
T3 (216)	7.78 ± 3.61 [a]	27.02 ± 7.13 [a]	7.27 ± 2.4 [a]	28.77 ± 4.15 [a]

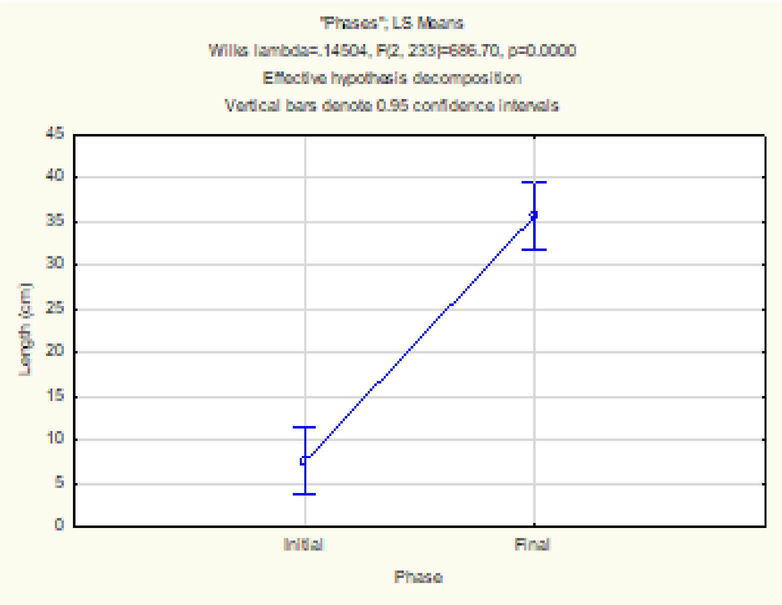
The different letters between the lines of each column represent the statistical differences according to analysis of variance (One-way ANOVA) and Tukey test, at a significance level of 95%.

Table 4. Mean and standard deviation values for the Initial and Final Length (cm) of plants in the different treatments.

Treatment (fish/m³)	**Average Initial Lenght (cm)**	**Average Final Length (cm)**
T1 (72)	9.42 ± 3.85 [a]	33.27 ± 8.83 [a]
T2 (144)	8.43 ± 4.40 [a]	36.57 ± 6.99 [a]
T3 (216)	7.52 ± 0.35 [a]	27.90 ± 1.23 [a]

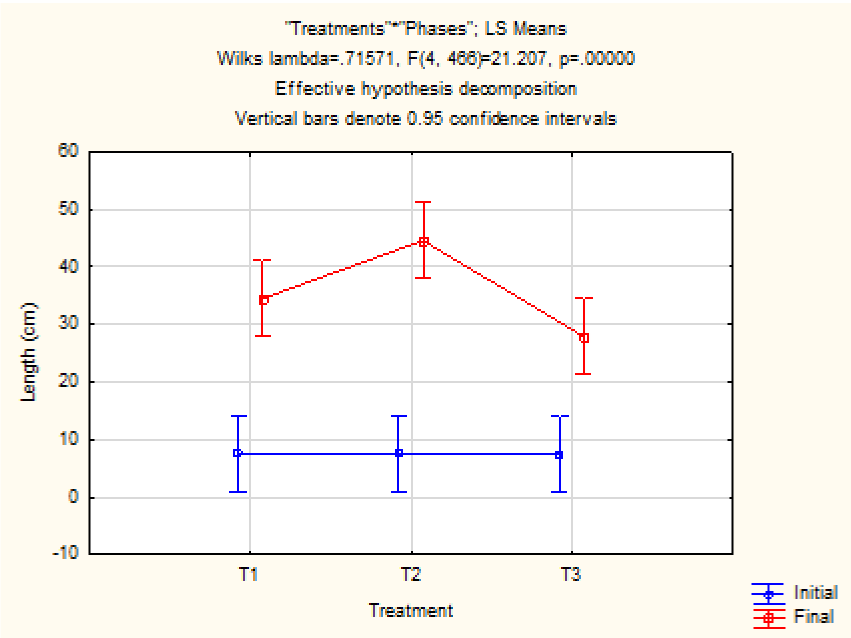
The different letters between the lines of each column represent the statistical differences according to analysis of variance (One-way ANOVA) and Tukey test, at a significance level of 95%.

Figure 9. Graph representing the length (cm) of the plants in the phases of the experiment.



Source: Author's gallery.

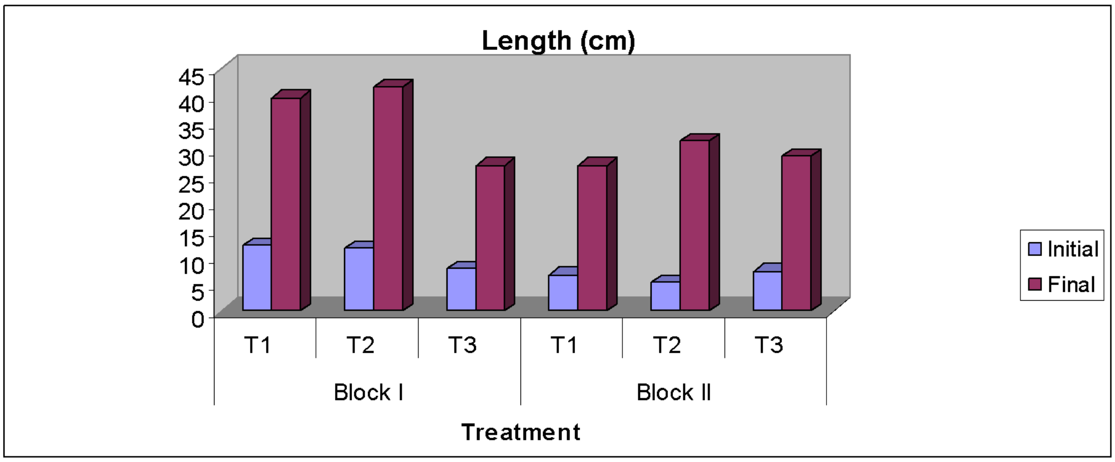
Figure 10. Graph representing the length (cm) of the plants in the phases of the experiment by treatment.



Source: Author's gallery.

Despite not having presented statistical differences, comparing the final length (cm) of the plants in all treatments, it is observed that Block I presented the best results of the research, highlighting treatments T1 and T2 (Figure 11).

Figure 11. Graph of the initial and final length (cm) of the experimental plants for each treatment in each Block.



Source: Author’s gallery.

Regarding plant weight (g), all treatments showed differences between the beginning and end of the experiment (Figures 12 and 13) and no significant differences were found between treatments (Table 5 and 6). However, as for the length, the best results were obtained in T1 and T2 of Block I, while in T3 of Block II the lowest weight values were registered (Figure 14).

Table 5. Initial and Final Weight Values (g) of plants in different treatments and between Blocks I and II.

	Block I		Block II	
Treatment (fish/m³)	Average Initial Weight (g)	Average Final Weight (g)	Average Initial Weight (g)	Average Final Weight (g)
T1 (72)	1	56.6	0.8	26.9
T2 (144)	1.1	55.8	1.6	35.4
T3 (216)	1.2	29.6	1.1	18.9

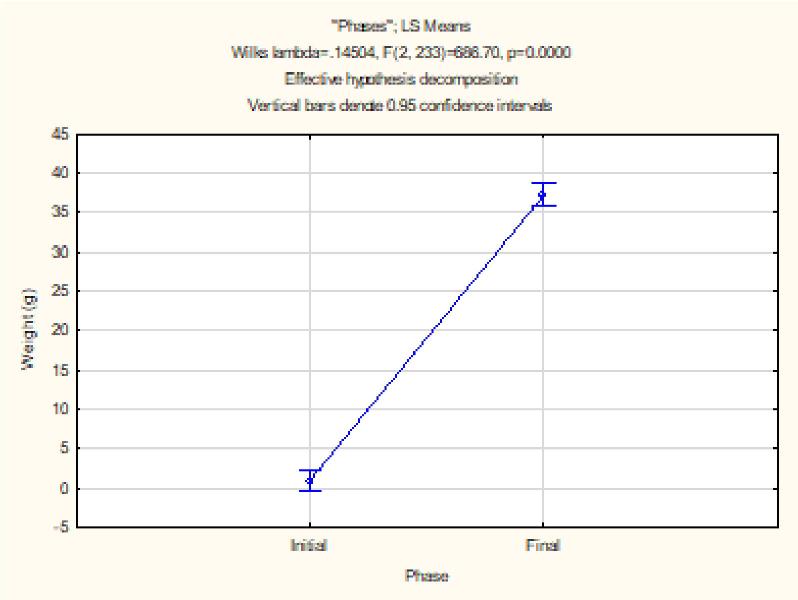
Source: Author's gallery.

Table 6. Mean and standard deviation values for Initial and Final Weight (g) of plants in the different treatments.

Treatment (fish/m³)	**Average Initial Weight (g)**	**Average Final Weight (g)**
T1 (72)	0.90 ± 0.14 [a]	41.75 ± 21.00 [a]
T2 (144)	1.35 ± 0.35 [a]	45.60 ± 14.42 [a]
T3 (216)	1.15 ± 0.07 [a]	24.25 ± 7.56 [a]

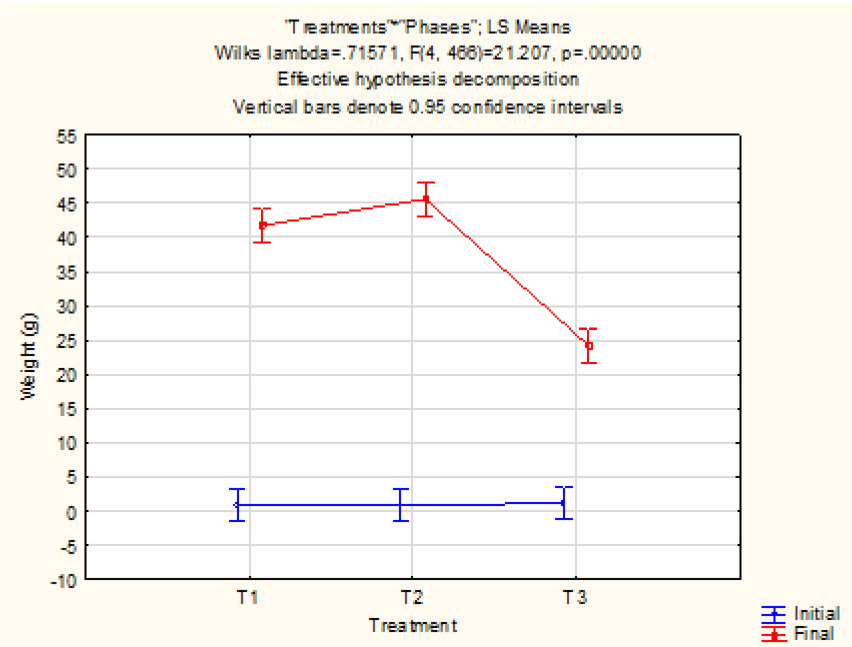
The different letters between the lines of each column represent the statistical differences according to analysis of variance (One-way ANOVA) and Tukey test, at a significance level of 95%.

Figure 12. Graph of initial and final weights (g) of the plants in the experiment.



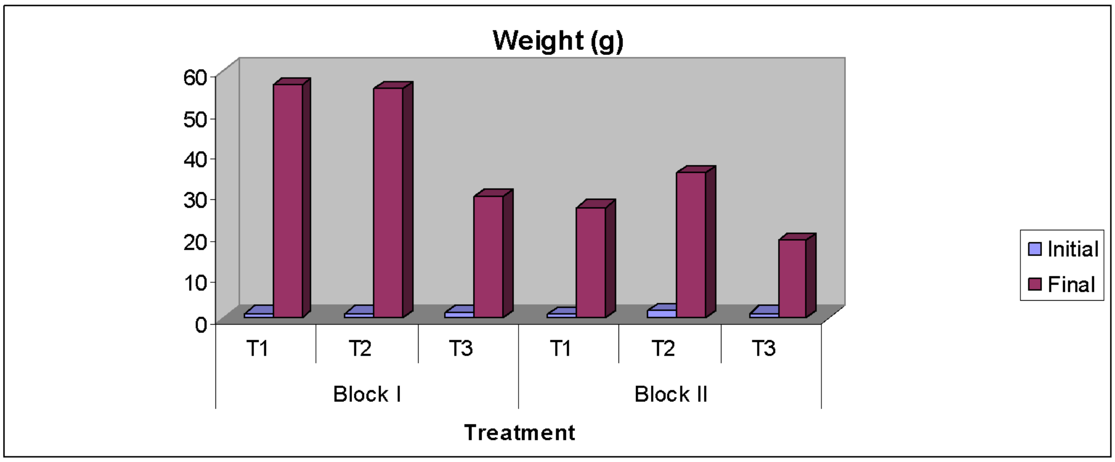
Source: Author’s gallery.

Figure 13. Graph representing the initial and final weights (g) of the plants for each treatment.



Source: Author’s gallery.

Figure 14. Graph representing the weights (g) of plants at the beginning and end of the experiment for each treatment per Block.



Source: Author's gallery.

The results of weight (g) of plants in this experiment, despite not showing statistical differences, demonstrate that the treatments T1 and T2 plants had better performance, with T2 as the best treatment (Figures 15 to 18). Ferrarezi and Bailey (2019), who carried out an aquaponic experiment like the one in question during the summer, but in the northern hemisphere in temperate climate, conducted two trials to identify basil cultivars suitable for outdoor tropical aquaponic production in the Commercial Aquaponic System of University of the Virgin Islands (UVI) of the USA. Five cultivars of basil were evaluated in the summer of 2015 and seven cultivars in the autumn of 2015, finding higher yields during the summer, which was calculated from May to August, in comparison with the fall, calculated from September to November. Also, they indicate that basil has production potential in the studied system as a special, short-season and high-value crop.

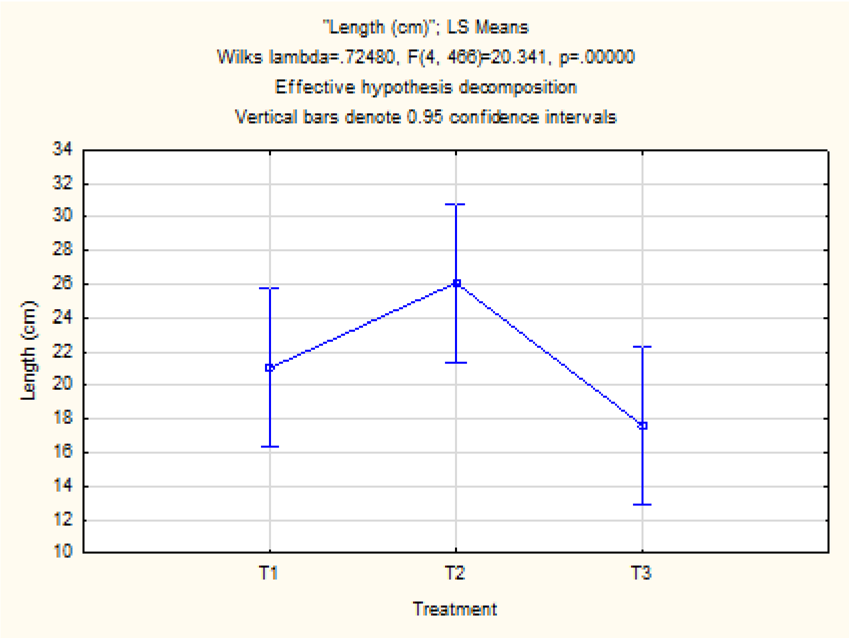
Abbey et al. (2021), who also carried out an experiment in the Northern Hemisphere, testing different varieties of basil in aquaponic systems of different conformations of the varieties and species of fish, finding average fresh mass weight (g) of all treatments of 9.6g/plant , being that in the best treatment the plants reached 69.5g/plant of fresh mass and the second best of 23.9g/plant. In the experiment in question, the average was 37.2g/plant and T2 presented an average of 45.6g/plant, and like the other treatments, they are within the weight spectrum found by the aforementioned authors.

In the study no additional fertilizers were used, but factors that can enhance plant production in aquaponics are the addition of micro and macro nutrients, as observed by Angkah et al. (2020). The authors carried out an experiment to optimize the dosage of mica, a phyllosilicate potassium mineral rock used as a fertilizer in agriculture, for the best system growth of aquaponic basil in association with Nile tilapia. It was confirmed that the introduction of mica had a positive impact on the plant, but showed a sign of stress in fish, which, however, did not cause a significant change in fish growth, and can be used in future work.

The plants grown in this experiment showed a dark green hue befitting healthy plants, in addition to being very palatable. The characteristics of aquaponic products were investigated by Yue et al. (2020), analyzing the acceptability of 105 consumers to three basil cultivars (Nufar, Genovese and Eleonora) in two types of aquaponic cultivation, both using Cyprinus carpio, the common carp, one in a greenhouse and the other in a shed, compared to hydroponics. The authors found more intense flavors of the plants grown in hydroponics, but the plants grown in aquaponics in the greenhouse showed less bitterness, demonstrating the food acceptance of this plant.

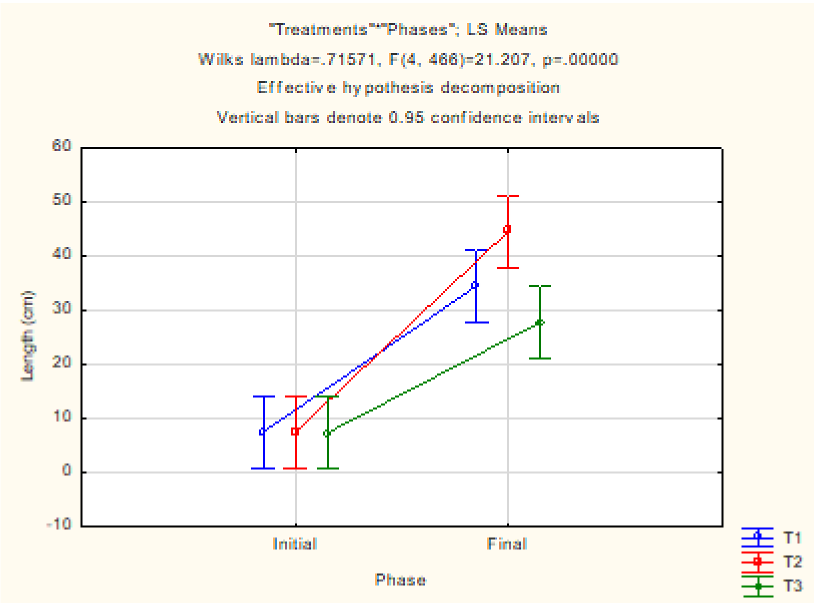
Plant growth data from this work demonstrated the viability of aquaponics in the production of basil in a tropical climate, as also presented by Barbosa (2011), Hundley and Navarro (2013) and Hundley et al. (2018).

Figure 15. Graph of the final length (cm) of the experimental plants for each treatment.



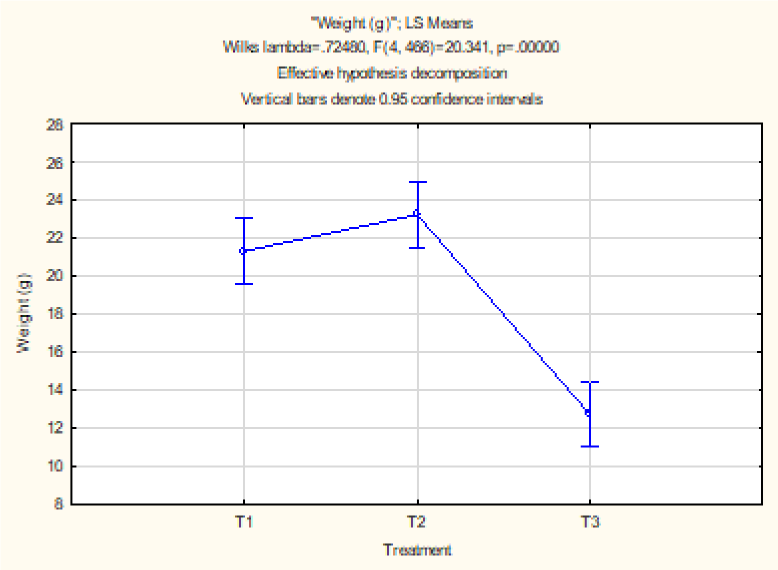
Source: Author's gallery.

Figure 16. Graph of initial and final length (cm) of plants by phase of the experiment for each treatment.



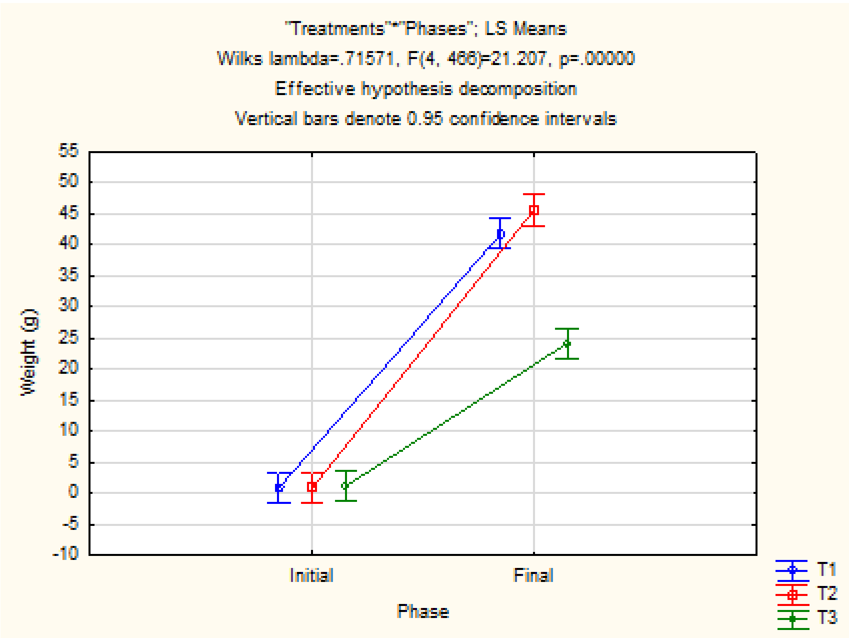
Source: Author's gallery.

Figure 17. Graph of average weight (g) of plants for each treatment.



Source: Author's gallery.

Figure 18. Initial and final weight (g) graph of experimental plants for each treatment.



Source: Author's gallery.

3.3 Fish

Nile tilapia fingerlings, Oreochormis niloticus, showed growth in all parameters analyzed and in all treatments (Table 7 and 8).

Table 7. Values of average weight (g), standard length (SL) and total length (TL), in centimeters (cm) initial and final, for the different treatments and between Blocks I and II.

	Block I						**Block II**					
Treatment (fish/m³)	Average Initial Weight (g)	Average Final Weight (g)	Initial SL (cm)	Final SL (cm)	Initial TL (cm)	Final TL (cm)	Average Initial Weight (g)	Average Final Weight (g)	Initial SL (cm)	Final SL (cm)	Initial TL (cm)	Final TL (cm)
T1 (72)	0.76	2.88	2.3	4.2	3.3	5.1	0.56	2.6	2.9	3.7	3.1	5.7
T2 (144)	0.68	2.28	2.5	3.8	3.2	4.8	0.56	2.36	3.0	3.6	3.3	4.9
T3 (216)	0.6	1.16	2.5	3.2	3.2	3.9	0.56	1.96	2.4	3.5	3	4.5

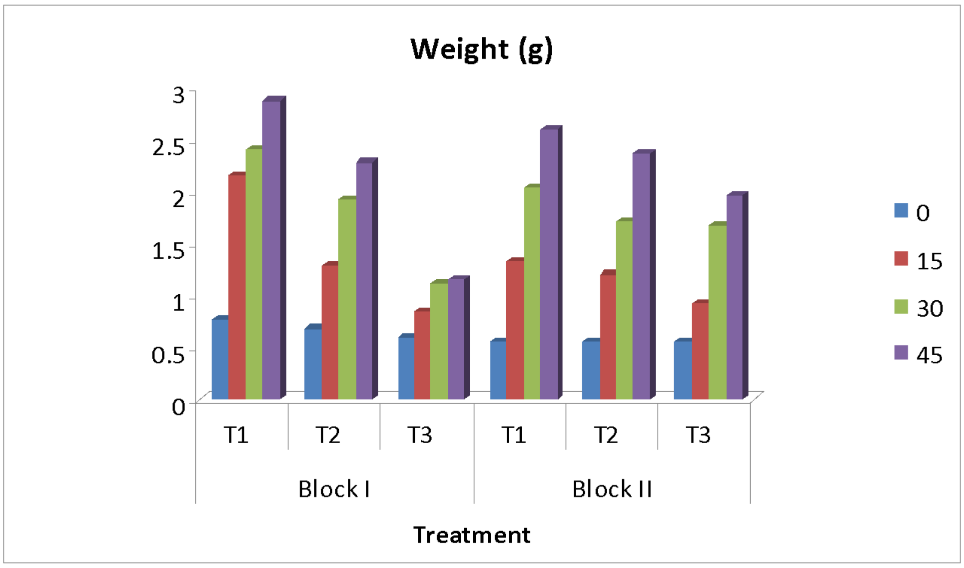
Table 8. Values of average weight (g), standard length (SL) and total length (TL), in centimeters (cm) at the beginning and at the end, for the different treatments.

Treatment (fish/m³)	**Average Initial Weight (g)**	**Average Final Weight (g)**	**Initial SL (cm)**	**Final SL (cm)**	**Initial TL (cm)**	**Final TL (cm)**
T1 (72)	0.66 ± 0.14 [a]	2.74 ± 0.19 [a]	2.64 ± 0.38 [a]	3.95 ± 0.34 [a]	3.26 ± 0.10 [a]	5.44 ± 0.43 [a]
T2 (144)	0.62 ± 0.08 [a]	2.32 ± 0.05 [a]	2.80 ± 0.34 [a]	3.75 ± 0.19 [a]	3.28 ± 0.04 [a]	4.89 ± 0.04 [a]
T3 (216)	0.58 ± 0.02 [a]	1.56 ± 0.56 [a]	2.50 ± 0.10 [a]	3.39 ± 0.19 [a]	3.13 ± 0.10 [a]	4.25 ± 0.40 [a]

The different letters between the lines of each column represent the statistical differences according to analysis of variance (One-way ANOVA) and Tukey test, at a significance level of 95%.

The analyzes of the biometric parameters of fish, measured during the biweekly samplings, demonstrate that for the parameter of weight (g), the T3 of the two blocks presented the smallest differences between the days sampled, as well as the smallest final results, with the T3 of Block I results very different from the others (Figure 19).

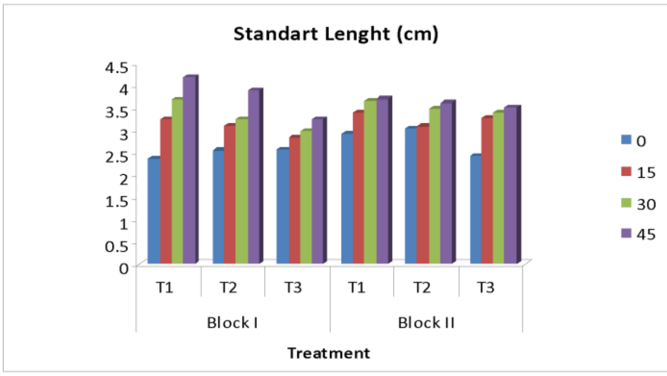
Figure 19. Graph representing the average weight of fish (g) for each treatment in biweekly biometrics for each Block.



Source: Author’s gallery.

In the standard length (cm), in all four biometrics performed during the experiment, the animal growth was recorded, and in some treatments the fish grew more between the first fortnights and tended to decrease the growth rate in the subsequent fortnights, while other treatments the opposite occurred (Figure 20). Although there were no statistically significant differences between treatments, it is noted that, as for weight, the best treatments were T1 and T2 of Block I and the one with the lowest growth rate was T3.

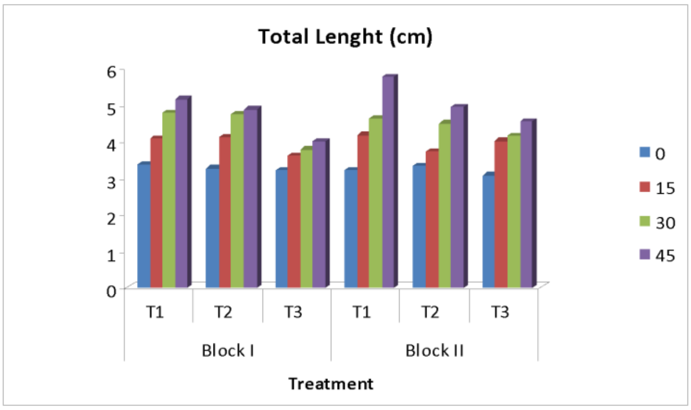
Figura 20. Gráfico representando o comprimento padrão (cm) dos peixes de cada tratamento nas biometrias quinzenais para cada Bloco.



Source: Author’s gallery.

O comprimento total dos peixes também apresentou crescimento em todos os tratamentos, porém, diferente dos parâmetros de peso e comprimento padrão, os indivíduos amostrados do T1 do Bloco II apresentaram os maiores índices (Figura 21). O T3 do Bloco I foi o que apresentou menor resultado para o parâmetro.

Figure 21. Graph representing the total length (cm) of fish from each treatment in biweekly biometrics for each Block.



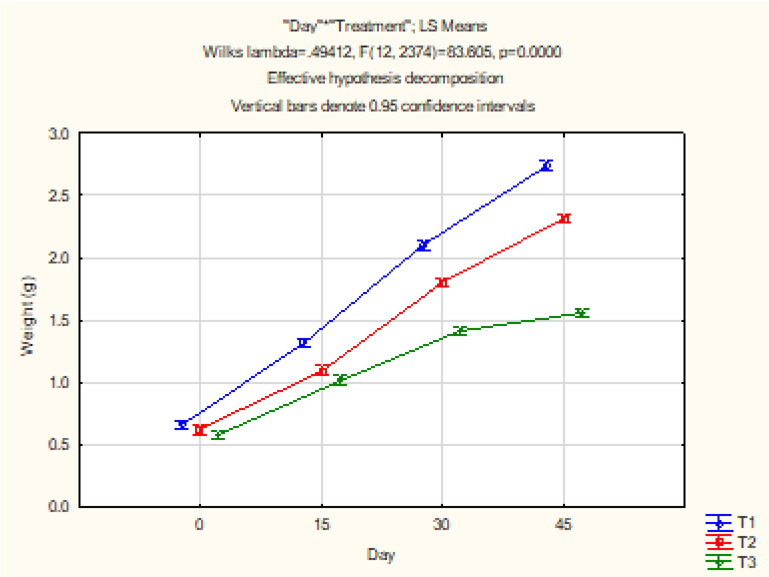
Source: Author’s gallery

The results obtained in the experiment show a representative growth for the sampling period (Figures 22 to 25), as shown by Santos et al. (2009), where throughout the experiment the fish acquired higher values for weight and length. Knaus & Palm (2017) worked comparing common carp fingerlings and Nile tilapia in conformations of aquaponic systems of substrates using two different plant species, finding a better combination of tilapia with tomato and common carp with cucumber and suggesting that the use of various animal species to increase plant yields.

When analyzing the results for the animal production parameters, in all treatments and in both blocks they presented growth. Regarding the performance of fish and plants, the work in question presented a null relationship between fish stocking density and plant growth, corroborating the H0, presenting results different from those found by Hundley et al. (2018), in which the increase in density was proportional to the highest values for weight and length of tilapia fingerlings. Also different from what was found by Patil et al. (2019), who studied the growth performance of Carassius auratus fingerlings and basil, Ocimum basilicum, reared in an aquaponic substrate system. The authors used three different fish stocking densities, 500 m^{-3}, 600 m^{-3} and 700 m^{-3}, and the basil plants were planted at a density of 20 m^{-2}, finding a positive relationship between the stocking density and the greatest results in the parameters of fish and vegetable production.

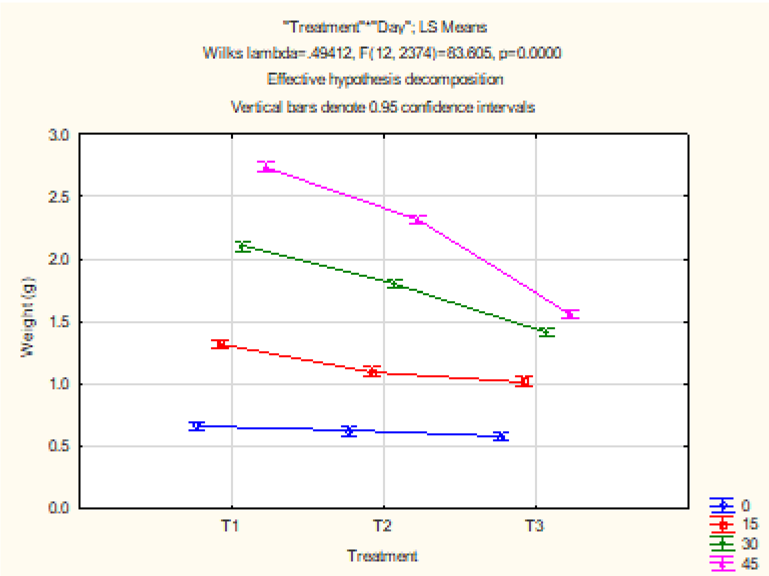
Although the Nile tilapia, Oreochromis niloticus, is one of the most studied species in aquaponic systems (LOVE et al., 2015), studies that analyze the growth of fingerlings of this species in aquaponic systems are still scarce, being found, but also scarce, works using Cyprinus carpio fingerlings in aquaponic systems in India and Bulgaria (HUSSAIN et al., 2015; SIRAKOV AND VELICHKOVA, 2018; SIRAKOV et al., 2018; VELICHKOVA et al., 2020).

Figure 22. Graph representing fish weights (g) in biweekly biometrics of each treatment.



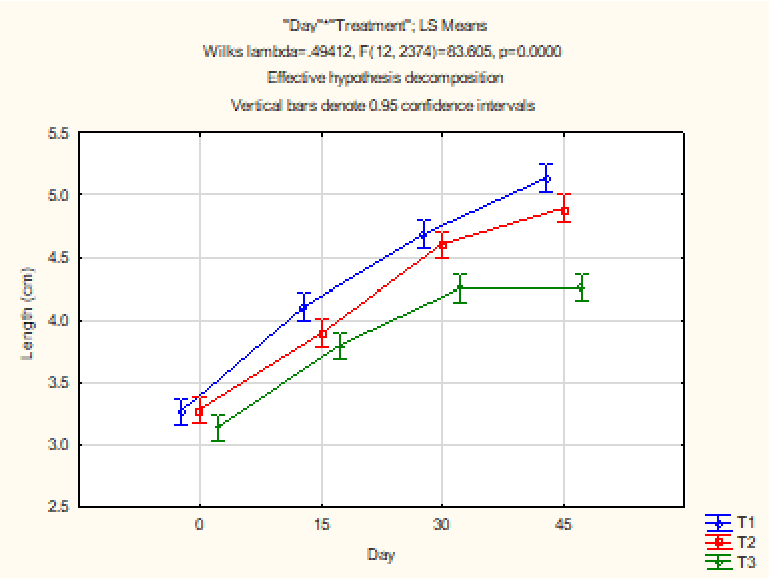
Source: Author's gallery.

Figure 23. Graph representing fish weights (g) of each treatment in biweekly biometrics.



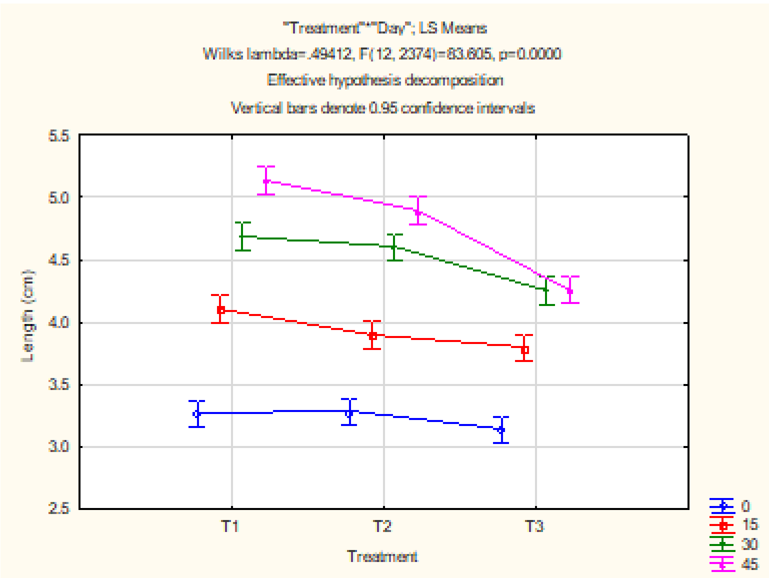
Source: Author's gallery.

Figure 24. Graph representing the length (cm) of the fish in the biweekly biometrics of each treatment.



Source: Author's gallery.

Figure 25. Graph representing the standard length (cm) of the fish of each treatment in biweekly biometrics.



Source: Author's gallery.

4 CONCLUSION

According to what was observed in this work, tropical aquaponic systems constituted by Nile tilapia in association with basil have productive viability, being interesting its use by producers who wish to cultivate food in a more sustainable way. As the results did not show differences between the treatments, we suggest that for future work higher fish densities should be considered, as it may demonstrate differences between treatments, in addition to being able to favor profits for producers. It is expected that further work involving the growth of fingerlings in aquaponic systems can be carried out, expanding the spectrum of research in the field of aquaponics.

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How to quote this article

Navarro, Rodrigo Diana, et al. Growth of fingerlings in different stocking densities in tropical aquaponic system of basil production. Ciência e Natura, Santa Maria, v. 43, e95. Available in:
https://doi.org/10.5902/2179460X63222.