LETTUCE PRODUCTION IN AQUAPONIC AND BIOFLOC SYSTEMS WITH SILVER CATFISH *Rhamdia quelen*

Andréa Ferretto da ROCHA[1]; Mario Luis BIAZZETTI Filho[2]; Marcia Regina STECH[1]; Raquel Paz da SILVA[3]

ABSTRACT

Aquaponic and biofloc systems have advantages when compared to conventional food production, but studies that associate both systems are incipient. The aim of this study was to evaluate the development of *Lactuca sativa* in hydroponic and aquaponic systems (with *Rhamdia quelen*) with or without bioflocs using minimal infrastructure. Hydroponic (H-system), aquaponic (Aqua), and aquaponics with bioflocs (Aqua-BF) were evaluated in a randomized design. It did not use a greenhouse, and it used a single tank to produce vegetables and fish together. The stocking density of lettuce was 20 plants m^{-2}. A total of 168 *R. quelen* juveniles were used to Aqua and Aqua-BF. Total ammonia, nitrite, and turbidity of the water were higher to Aqua-BF than H-system and Aqua. Lettuces were significantly more productive in Aqua and Aqua-BF than H-system. There were no differences between Aqua and Aqua-BF for the parameters lettuce production and fish performance. Under the conditions of this study, it was possible to conclude that aquaponic farmers can use silver catfish, and aquaponic systems with and without bioflocs can improve the lettuce produce. The use of bioflocs in the aquaponic system may improve the productivity but needs a better study to optimize and simplify this technology.

Keywords: green vegetable; hydroponic; multitrophic system

PRODUÇÃO DE ALFACE EM SISTEMAS DE AQUAPONIA E BIOFLOCOS COM JUNDIÁ *Rhamdia quelen*

RESUMO

Aquaponia e sistema de bioflocos possuem vantagens quando comparados com sistemas convencionais de produção de alimentos, mas estudos que associam esses sistemas são incipientes. O objetivo deste estudo foi avaliar o desenvolvimento de *Lactuca sativa* em sistemas hidropônicos e aquapônicos (com *Rhamdia quelen*) com ou sem bioflocos utilizando mínima infraestrutura. Hidroponia (H-system), aquaponia (Aqua) e aquaponia com bioflocos (Aqua-BF) foram avaliados em delineamento inteiramente casualizado. A alface e os peixes foram produzidos juntos em uma única caixa, sem o uso de estufa. Foram utilizadas 20 plantas m^{-2}. Foram utilizados 168 juvenis de jundiás para Aqua e Aqua-BF. Amônia total, nitrito e a turbidez da água foram maiores para Aqua-BF que para o H-system e Aqua. A produção de alface foi significativamente maior em Aqua e Aqua-BF dos que em H-system. Não houve diferenças entre Aqua e Aqua-BF para produção de alface e desempenho dos peixes. Sob as condições deste estudo, foi possível concluir que o jundiá pode ser usado em sistemas aquapônicos com ou sem bioflocos e que ambos os sistemas podem melhorar a produção de alface. O uso de Aqua-BF pode melhorar a produtividade, mas precisa de um melhor estudo para otimizar e simplificar o uso desta tecnologia.

Palavras-chave: vegetais; hidroponia; sistema multitrófico

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[1] *Research Center Herman Kleerekoper, State Foundation for Agricultural and Livestock Research (Fepagro), Fepagro Aquaculture & Fishing. BR 101, km 53 - Post office box 03 - Terra de Areia – CEP: 95535-000 – RS – Brazil. e-mail: andreafdarocha@hotmail.com (corresponding author); marciareginastech@gmail.com*

[2] *Federal University of Rio Grande do Sul (UFRGS). RS-030, km 92, n.11.700 – CEP: 95590-000 – Tramandaí – RS – Brazil. e-mail: biazzetti@live.com*

[3] *State Foundation for Agricultural and Livestock Research (Fepagro), Fepagro North Coast. RS 484, km 05 – CEP: 95530-000 – Maquiné – RS – Brazil. e-mail: ranitapaz1970@gmail.com*

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INTRODUCTION

The lettuce *Lactuca sativa* is cultivated throughout Brazil, especially by family farms (SOARES *et al.,* 2015). Lettuce is globally grown for fresh consumption in salads, and it is used on a large scale in hydroponics, called NFT (Nutrient Film Technique) (CARVALHO *et al.*, 2015). When producing vegetables, traditional hydroponics systems rely on fertilizer solutions to meet the nutritional needs of plants that grow in water. The use of green vegetables is recommended for aquaponics since it tolerates high levels of water in their roots and the significant variations in the levels of nutrients that are dissolved in the nutrient solution without symptoms of nutritional deficiency (EFFENDI *et al.,* 2016). The aquaponic system use for plant growth the available fish water that is rich in fish waste as nutrients, which become available through the microbiological activities that occur in the aquatic environment (MARTINS *et al*., 2010; GODDEK *et al.,* 2015). The aquaponics system has advantages when compared to conventional agricultural ecosystems. For example, aquaponic is more efficient in the use of water and area and waste from other cultures; higher productivity; lower cost of inputs and labor; greater biosafety contribution; less need for monitoring water quality; easy system management (RAKOCY *et al*., 2006; GRABER and JUNGE, 2009).

The aquaponic has been predominantly spread throughout the world through home-scale producers (HUNDLEY *et al.,* 2013). Most hydroponics operations are in controlled environment facilities, but a recent international survey shows that just 47% of aquaponic systems were outdoors, 46% were in greenhouses or high tunnels, 28% were inside buildings, and 3% were on rooftops (LOVE *et al*., 2014). Studies to meet the first steps of amateur producers in cities need to be produced.

In shrimp and fish farms the bioflocs system gets the better purpose of water, through the benefit of aerobic heterotrophic culture system and minimal water exchange. In this system, the nitrogenous compounds presented in the water are converted into bacterial biomass, called bioflocs, from the incorporation of ammonia by heterotrophic bacteria in the environment, acting as a biofilter (AVNIMELECH, 2007).

Aquaponic and biofloc systems are considered promising and an emerging approach, which combines intensive production with waste recycling and water conservation (KLINGER and NAYLOR, 2012). Albeit studies associate that aquaponic and biofloc systems are incipient, the use of bioflocs in the aquaponic system may provide ideal conditions for bacteria to control water quality that will promote the recycling of nutrients in the water (AVNIMELECH, 2007).

FAO (2016) points out that the in the last five decades the fish production has been growing at a constant rate, being that the global consumption *per capita* of fish has increased. Therefore, in the future, the agriculture sector will need to produce more with less. The uses of biofloc and aquaponics systems are helping in the increase of aquaculture production. Starting from the elements of efficient resource use by integrating food productions systems and reducing inputs and waste, aquaponics systems can become an additional means to tackle the global challenge of food supply (FAO, 2016). WASIELESKY *et al*. (2006) mention the advantages of the bioflocs system, as there is zero water exchange, an increase of density and biosafety, reduction of the amount of protein in the rations and minimal environmental impact.

The silver catfish (*Rhamdia quelen*) is distributed in Central and South America, and it is found in rivers, lakes, and streams. This species is adapted to different methods of rearing (BALDISSEROTTO and RADÜNZ NETO, 2004), and its commercial production has been encouraged in Southern Brazil.

Until this moment, there is no study about lettuce crop in an aquaponics system in association with biofloc and silver catfish. This study presented preliminary results of the production of lettuce in floating raft system without the use of solids separator and using the same tank to produce vegetables and fish, as well without a greenhouse, outside and in semi-temperate climate. As well, it evaluated the development of *L. sativa* in hydroponic and aquaponic systems (with *R. quelen*) with and without bioflocs using minimum infrastructure.

The experimental unit (Figure 1) consisted of rectangular fiberglass tanks (length: 5.0 m, height: 0.4 m, width: 0.5 m - 1,000 L), with screen partitions delimiting 1.75 m^2 for lettuce growing area in a floating raft system and 0.75 m^2 for the fish. The delimitations were made using mosquito netting (0.26 mm). The water flowed through them using a submerged pump (650 L h^{-1}, 11 W, 60 Hz, 220 v, Sarlo Better®), which also helped with aeration.

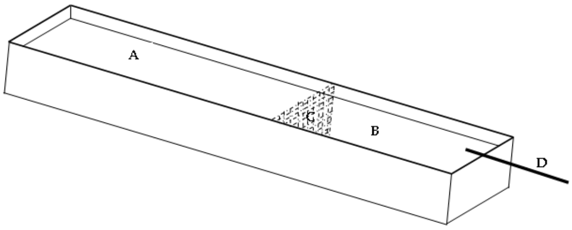

Figure 1. Scheme of rectangular fiberglass tanks (length: 5.0 m; height: 0.4 m; width: 0.5 m - 1,000 L). Where A: 1.75 m^2 for lettuce growing area in a floating raft system; B: 0.75 m^2 for fish; C: mosquito netting (0.26 mm); D: clean water supply.

Experimental conditions

The experiment was carried out between July 17 and September 01, 2015. During the trial period, the average air temperature was 18.6°C (maximum 33.7 and minimum 7.8°C), the average relative humidity of the air was 85.2% (maximum 98% and minimum 28%) and rainfall accumulated was 300.4 mm.

Lettuce plantlets (smooth variety, 4-7 leaves) arranged in floating rafts (polystyrene; spaced in 10 x 10 cm; cells filled with the commercial substrate) and then stocked in the tanks at a density of 20 plants m^{-2}. In the H-system treatment, the only occupied area was the one designed for the vegetables. Natural fresh water (electrical conductivity: 46 µS cm^{-1}; total dissolved solids: 25 mg L^{-1}) filled all tanks. There was a slow flow of water (10% volume per day) in Aqua-treatment tanks. The Aqua-BF treatment had no water exchange, but a submerged pump in each tank promoted the flow of the bioflocs into the water column, and it minimized the settling. Initially, a preformed biofloc reactor (electrical conductivity: 1700 µS cm^{-1}; total dissolved solids: 910 mg L^{-1}) filled 10% of the tank volume with bioflocs (density of 35 mL L^{-1}), and a new input of bioflocs was performed on the 25th day to keep the initial density. This reactor contained bioflocs "matured" and it made from organic fertilization with added molasses, wheat bran and commercial rabbit diet in a C:N ratio at around 20:1, following the instructions of AVNIMELECH (2009). In H-system two commercial liquid fertilizers were added to the water to provide the macro and micronutrients required for the growth of vegetables and the pattern pH. Solution A (N: 65 g L^{-1}; P_2O_5: 104 g L^{-1}, K_2O: 104 g L^{-1}, B: 6.5 g L^{-1}, Ca: 13.0 g L^{-1}, Cu: 2.6 g L^{-1}, Fe: 1.3 g L^{-1}, Mn: 6.5 g L^{-1}, Mg: 13.0 g L^{-1}, Mo: 0.65 g L^{-1}, S: 28.21 g L^{-1}, Zn: 13.0 g L^{-1}, and 5.97% of amino acids), and solution B (N: 12.7 g L^{-1}; P: 381 g L^{-1}). In the beginning was added 300 mL of Solution A and 100 mL Solution B. After 28 days was reapplied 100 mL of Solution A.

Water analyses

During the study, the water quality was monitored. Every two days dissolved oxygen and water temperature were measured using a handheld equipment (YSI® 55), electrical conductivity (EC) and total dissolved solids (TDS) using a portable conductivity meter (EC/TDS, HI 99300, Hanna Instruments®). Every ten days, the total suspended solid (TSS) was verified by volatilization gravimetric method according to STRICKLAND and PARSONS (1972). On 3rd, 5th, 11th and 27th days of the study the concentrations of the total ammonia (TAN) were measured by a colorimetric method using an UV-visible spectrophotometer (Quimis®) according to KOROLEFF (1976); and the non-ionized ammonia (NH_3-N) measured by colorimetric kit (Labcon®). The other water analyses were performed weekly. A pH indicator tape 0-14 (Macherey-Nagel®) was used to measure pH, total Alkalinity (mg $CaCO_3$ L^{-1}) was determined by a titrimetric method as described in BAUMGARTEN *et al*. (1996). Nitrite (NO_2-N) was measured by the colorimetric method using an UV-visible spectrophotometer (Quimis®) according to STRICKLAND and PARSONS (1972). Turbidity (NTU - nephelometric turbidity units) was measured using a portable turbidity meter (HI 98703, Hanna Instruments®). The settleable solids (bioflocs volume) were measured using Imhoff cones on the 25th day to verify the need for adding a new dose of bioflocs.

Fish performance

Rhamdia quelen juveniles (total n = 168; initial weight of 19.53 ± 5.13 g) were randomly placed into six tanks corresponding to treatments Aqua and Aqua-BF, with similar biomass in all tanks (504.64 ± 38.72 g). The fish were kept and managed following the protocol approved by the Ethics Committee on Animal Use of Fepagro Animal Health (number 25/15). Fish were fed a commercial extruded diet at a rate of 3% biomass, divided into three daily portions. The levels of feed guaranteed by the manufacturer were: 32% crude protein kg^{-1}; 300 mg vitamin C kg^{-1}; 10% humidity; mineral matter 12%; fibrous matter 5.5%; EE (min.) 60 g kg^{-1}; Ca: 5 (min.) - 25 (max.) g kg^{-1}; P: (min.) 6 g kg^{-1}; Cu: 5 mg kg^{-1}; Fe: 30 mg kg^{-1}; Mn: 30 mg kg^{-1}; Zn: 60 mg kg^{-1}. Survival rate, final weight, weight gain (semi-analytical digital scale, 0.001 g, Shimadzu®,) and feed conversion ratio (feed consumed/weight gain) of the fish were evaluated.

Lettuce crop

The trial period ended on the 46th day after transplanting, and the plants were harvested manually. Ten lettuces of each repetition were used to evaluate the plant height (cm), head diameter (cm), root length (cm), number of leaves per plant, fresh weight of leaves and roots (g), dry weight of leaves and roots (g) and the total fresh and dry weight per plant (g). The materials were placed in paper bags and dried in a laboratory oven (36 h at 70°C) and weighed on an analytical scale (0.001 g, Marte®). A portable chlorophyll meter (Clorofil LOG®, model CFL 1030, Falker Agricultural Automation) was used to perform the analyses of chlorophyll *a*, *b* and chlorophyll (*a*+*b*), in triplicate (three analyses per leaf), one leaf per plant, on top of the plant on each of the ten plants. The results were in Chlorophyll Index Falker (CIF).

Statistical analyses

All results were assessed for normality by the Kolmogorov-Smirnov test, to homoscedasticity by SNHT and the results were expressed as mean value ± standard deviation. The Dixon test was performed to evaluate the presence of outlines. Statistical analysis was performed using statistical software XLSTAT® version 2014.5.01 software (XLSTAT 2014), and the level of significance adopted was 95% (α = 0.05). To evaluate the development of the fish was used the nonparametric Wilcoxon test. The other variables were analyzed using Kruskal-Wallis test with Dunn's post hoc test (CALLEGARI-JACQUES, 2007).

RESULTS

The production systems evaluated in this study presented preliminary results that pointed to the possibility of using the same tank to produce vegetables and fish together. Table 1 shows the water quality parameters of the three systems used for food production. No significant differences were observed (P>0.05) for temperature, TSS, and non-ionized ammonia. The systems had significant differences (P<0.05) for the others water parameters. Aqua-BF shows higher values than the H-system and Aqua for total ammonia, nitrite, and turbidity. The Aqua and Aqua-BF systems had no difference between each other, but the H-system had higher values of dissolved oxygen and pH was more acidic. There were significant differences between three systems for conductivity, TDS, and alkalinity. Mean values of this study for EC of H-system water was higher than in Aqua and Aqua-BF.

Table 2 shows the results of fish performance during the experimental period. In this study, there was no significant difference (P>0.05) in the growth of fish for the use of bioflocs added to the tanks. The survival was 100% in both treatments.

The systems Aqua and Aqua-BF were more significantly productive in the development of lettuce than the H-system because there were higher averages to head diameter, height, stem diameter, root length, number of leaves, final weight of leaves and stems, final weight of roots, final dry weight of leaves and stems, and final dry weight of roots in these two treatments. Aqua and Aqua-BF systems presented no difference for those variables. The results of chlorophyll *a* and *b* were significantly superior to Aqua than to the H-system and Aqua-BF (P<0.05) (Table 3).

Table 1. Water mean values (± standard deviation) of hydroponic (H-system), aquaponic (Aqua) and aquaponic with bioflocs (Aqua-BF) systems used to lettuce (*Lactuca sativa*) production, and probability (Kruskal-Wallis test).

Parameter	H-system	Aqua	Aqua-BF	*P*-value
Temperature (°C)	18.0 ± 2.6	18.0 ± 2.50	18.0 ± 2.53	0.832
Total suspended solids (mg L^{-1})	225 ± 241	375 ± 391	425 ± 238	0.129
Ammonia (NH_3-N; mg L^{-1})	0.006 ± 0.003	0.010 ± 0.015	0.021 ± 0.038	0.691
Total ammonia nitrogen (mg L^{-1})	1.91 ± 2.07^a	0.66 ± 0.99^{ab}	0.37 ± 0.55^b	0.022
Nitrite (NO_2-N; mg L^{-1})	0.060 ± 0.086^b	0.046 ± 0.049^b	0.224 ± 0.266^a	0.002
Turbidity (NTU)	6.8 ± 5.2^b	7.3 ± 6.6^b	211.6 ± 154.2^a	<0.0001
Dissolved oxygen (mg L^{-1})	7.11 ± 1.21a	6.52 ± 1.78^b	5.87 ± 1.85^b	<0.0001
pH	5.0 ± 0.9^b	7.0 ± 0.4^a	7.0 ± 0.6^a	<0.0001
Conductivity (µS cm^{-1})	341.5 ± 146.0^a	45.4 ± 6.0^c	172.5 ± 54.0^b	<0.0001
Total dissolved solids (mg L^{-1})	1834 ± 79^a	25 ± 3^c	92 ± 31^b	<0.0001
Alkalinity (mg $CaCO_3$ L^{-1})	4 ± 5^c	20 ± 10^b	54 ± 11^a	<0.0001

Different letters in the rows indicate significant differences by Dunn's test (P<0.05).

Table 2. Parameters of silver catfish (*Rhamdia quelen*) performance on day 46 (means values ± standard deviation) in aquaponics (Aqua) and aquaponics with bioflocs (Aqua-BF) systems, *P*-values (Kruskal-Wallis test).

Parameter	Aqua	Aqua-BF	*P*-value
Initial weight (g $fish^{-1}$)	20.00 ± 1.34	19.04 ± 0.54	0.181
Final weight (g $fish^{-1}$)	31.06 ± 1.29	31.18 ± 1.40	1.000
Weight gain (g $fish^{-1}$)	11.06 ± 0.55	12.14 ± 1.52	0.423
Daily weight gain (g $fish^{-1}$)	0.24 ± 0.01	0.26 ± 0.03	0.423
Feed conversion ratio	1.32 ± 0.14	1.15 ± 0.15	0.275

Table 3. Lettuce (*Lactuca sativa*) means values (± standard deviation) in hydroponics (H-system), aquaponics (Aqua) and aquaponics with bioflocs (Aqua-BF) systems, *P*-values (Kruskal-Wallis test).

Parameter	H-system	Aqua	Aqua-BF	*P*-value
Fresh weight (g $plant^{-1}$)	2.6 ± 0.6^b	24.6 ± 14.1^a	39.8 ± 30.9^a	<0.0001
Dry weight (g $plant^{-1}$)	0.48 ± 0.33^b	2.39 ± 1.23^a	3.68 ± 2.11^a	<0.0001
Root fresh weight (g $plant^{-1}$)	8.4 ± 2.16^b	28.1 ± 10.3^a	32.1 ± 14.0^a	<0.0001
Root dry weight (g $plant^{-1}$)	1.68 ± 0.41^b	3.33 ± 1.11^a	3.84 ± 1.54^a	<0.0001
Total fresh weight (g $plant^{-1}$)	10.7 ± 1.98^b	52.75 ± 24.28^a	76.67 ± 47.21^a	<0.0001
Total dry weight (g $plant^{-1}$)	2.14 ± 0.53^b	5.71 ± 2.22^a	8.36 ± 4.72^a	<0.0001
Root length (cm $plant^{-1}$)	7.4 ± 3.7^b	42.0 ± 6.9^a	39.3 ± 7.5^a	<0.0001
Height (cm $plant^{-1}$)	6.3 ± 0.7^b	12.0 ± 1.5^a	14.5 ± 3.7^a	<0.0001
Total number of leaves/plant	11 ± 2^b	17 ± 4^a	20 ± 7^a	<0.0001
Head diameter (cm $plant^{-1}$)	7.87 ± 0.8^b	15.7 ± 2.7^a	18.9 ± 4.8^a	<0.0001
Stem diameter (cm $plant^{-1}$)	0.72 ± 0.25^b	1.03 ± 0.20^a	0.93 ± 0.23^a	<0.0001
Chlorophyll *a* (CIF)	15.00 ± 2.35^b	16.96 ± 1.49^a	14.45 ± 2.26^b	<0.0001
Chlorophyll *b* (CIF)	2.89 ± 0.47^b	3.29 ± 0.40^a	2.73 ± 0.41^b	<0.0001
Chlorophyll *a*+*b* (CIF)	17.88 ± 2.80^b	20.25 ± 1.85^a	17.18 ± 2.64^b	<0.0001

Different letters in the rows indicate significant differences by Dunn's test (P<0.05).

DISCUSSION

The Aqua and Aqua-BF systems provided satisfactory environmental conditions for the development of fish during the period analyzed. The water quality parameters were within the characteristics considered suitable for the survival of silver catfish (BALDISSEROTTO *et al., 2*004). The silver catfish is known to have positive growth rates even under temperature conditions where other tropical species would stop developing (GARCIA *et al., 2*008). So the silver catfish can be used for aquaponic farmers of semi-temperate areas.

As a rule, dissolved oxygen levels should be maintained at around 5 mg L^{-1} or more in fish farm ponds and around the roots of the plants to ensure a healthy aquaponic system (RAKOCY, 2007). The lower oxygen levels observed in Aqua and Aqua-BF systems than observed in H-system were due to the consumption of oxygen by fish and aerobic microorganisms (HARGREAVES, 2013). However, the lower dissolved oxygen seen was not enough to impair fish and lettuce development.

The use of sedimentation or filtration in hydroponic and aquaponic systems to avoid blocking the systems are common (CORTEZ *et al.*, 2009); however, it was not used in this study to avoid damage to the bioflocs. There are many kinds of aquaponics systems. The most employed consists of an additional biofilter (e.g. media or gravel beds) through which the water passes before returning to the fish tanks associated with floating rafts (LOVE *et al.*, 2015). Usually, in aquaponic systems, the replacement may be lowered since plants uptake the nutrients in the water. Nevertheless, it may be needed to exchange some of the water occasionally, to keep the fish healthy and their welfare, since the systems work with recirculating water.

Using biofloc technology promotes a controlled increase of TSS by the presence of microbial flocs which serve as fish feed (AVNIMELECH, 2007). However, an optimal concentration of TSS may differ from each species and even from different stages of life and farming systems. POLI *et al*. (2015) indicated the level of TSS of 200 mg L^{-1} in the biofloc system for better development of silver catfish larvae. This study did not observe the benefit of the bioflocs in the fish growth, perhaps due to the high TSS levels found. In contrast, the addition of bioflocs poured into the Aqua-BF tanks promoted water quality even without water exchange, and with no deleterious effects on the plants. Furthermore, the use of biofloc in an aquaponic system did not result in any damage to the animals, which completed the study with 100% survival. The inoculant of bioflocs used in the Aqua-BF system came from a reactor fertilized with molasses. Both the dark molasses and the suspended particles reflected in an increase of turbidity of the Aqua-BF system. The higher turbidity inhibited the development of photoautotrophic microorganisms, such as phytoplankton, which it is positive. The proliferation of phytoplankton in the biofloc system is not desirable because it can cause wide fluctuations in dissolved oxygen, ammonia concentration and pH (BURFORD *et al*., 2003).

The electric conductivity (EC) found in this study was approximately 20% of the recommended by RAKOCY *et al*. (2006) for hydroponic and aquaponic systems. The lack of nutrients possibly interfered in the development of the plants. The H-system had the higher amount of ions dissolved in water (EC and TDS), but it did not reflect in higher plant growth. We did not perform a phytoplankton analysis, but these microorganisms were present in the H-system tanks. They may have damaged the plant growth due to the competition for nutrients in the H-system (EBELING *et al*., 2006). Also, ammonia (NH_3+NH_4^+) was higher in the H-system, and when it is the principal form of nitrogen, it is uptaken by plants (SAVVAS *et al*., 2006). These findings suggest the possibility of phytotoxicity of the plants by ammonia (QIU *et al*., 2014; SAVVAS *et al*., 2006) damaging lettuce development in the H-system.

The values of alkalinity found in Aqua and Aqua-BF were approximately 5.5 times to 13.5 times greater than H-system. BOYD (2015) explained that the association of fish, feed, and the presence of microalgae in the tanks naturally provoke the elevation of inorganic carbon, carbonate, and bicarbonate in water, raising alkalinity. The occurrence of denitrification processes carried out in anoxic microzones inside the bioflocs (EBELING *et al*., 2006), and plants that uptake nitrate and release OH^- in the water, raising pH and alkalinity too (CARRIJO *et al.*, 2000) what explain the higher value of alkalinity in bioflocs system. The bicarbonates are the responsible for keeping stable pH values in the water (SANTOS *et al.*, 2010), but at higher values require greater care in maintaining the ideal pH for the culture of lettuce, which is 5.5 and 6.5 (COSTA *et al.*, 2001). Therefore, controlling the pH of the H-system is easier than Aqua and Aqua-BF.

The pH affects the supply of nutrients in the water since the nitrification is inhibited at low pH (TANG and CHEN, 2015; ZOU *et al.*, 2016). Despite the fact that most hydroponic plants have an acceptable range of pH among 5.5 to 6.5 (CARMELLO and ROSSI, 1997), their best development is at a pH 5.8 to 6.2 (RAKOCY *et al.*, 2006), because the solubility of phosphorus, calcium, magnesium, and molybdenum sharply decreases at a pH lower than 6.0 (RAKOCY *et al.*, 2006). ZOU *et al.* (2016) obtained higher plant yield at pH 6.0 in aquaponics than at pH 9.0. In this study, Aqua and Aqua-BF systems showed an average pH of 7.0, deemed more appropriate to supply all biological components present in an aquaponic system, according to RAKOCY *et al.* (2006) and suitable for fish survival (BALDISSEROTTO and RADÜNZ NETO, 2004).

The evaluation of the chlorophyll, used as a physiological indicator, is necessary to assess the nutritional status of plants related nitrogen (ARGENTA *et al.*, 2001). Nitrogen plays in plants essential function in the formation of amino acids, proteins, enzymes, coenzymes, vitamins and pigments such as the chlorophyll molecules, determining the growth and development of plants and cropping productivity (LUZ *et al.*, 2008). Several studies indicate the relationship between the nitrogen and the concentration of chlorophyll in leaves (FERREIRA *et al.*, 2006; OLIVEIRA *et al.*, 2010). The results of chlorophyll *a*, *b* and *a*+*b* of this study did not indicate difference among Aqua-BF and H-system although these indexes were significantly higher in Aqua-system. On the other hand, plant development was different and superior in both aquaponics systems. LICAMELE (2009) also reported equal biomass and chlorophyll indexes in aquaponics compared to the hydroponics. However, in this research chlorophyll index was not considered a proper parameter because the system that had the highest index was not the same which presented the better development of plants.

The presence of heterotrophic bacteria and autotrophic bacteria in high density into bioflocs explain the higher values of the nitrite in Aqua-BF. Heterotrophic bacteria achieve the capture of ammonia and their transformation into microbial protein, whereas chemosynthetic autotrophic bacteria perform the oxidation of ammonia to nitrite and nitrite to nitrate (EBELING *et al.*, 2006). The nitrifying bacteria may also be associated with substrates present in the tank or roots of the plants (RAKOCY *et al.*, 2006). Biofloc system is comprised of heterotrophic, autotrophic and photoautotrophic microorganisms (BURFORD *et al.*, 2003), though the increase and prevalence of heterotrophic bacteria are desired to promote the decomposition of organic matter, to reduce the total ammonia nitrogen levels and to provide an additional food source for animals (AVNIMELECH, 1999). The literature reports that small amounts of substrate organic carbon could benefit nitrification (TANG and CHEN, 2015), corroborating with the findings in this study.

The higher average of total fresh and dry weight of plants, fresh shoot and root and dry weight and the total number of leaves observed in this study to Aqua and Aqua-BF, showed the possibility of better productivity than from H-system. However, in this study the trial occurred under the sky, without protection from rain, wind and temperature changes, with a minimum infrastructure, EC less than necessary, which possibly influenced the results obtained. RADIN *et al.* (2004) showed that lettuce produced under field conditions in the Rio Grande do Sul state had lower performance and the higher production cycle was greater than when produced in greenhouses.

One of the main advantages of using aquaponics systems is the possibility to optimize the resources used to benefit two or more cultures, as both fish and plants. Also, producing vegetables without the use of pesticides, since these would harm the fish. Setting this method of farming is interesting, economically and ecologically, as it achieves a growing market niche: the organic food. The literature reports that conventional aquaponic systems can produce about 7 kg of vegetables for every 1 kg of fish (GRABER and JUNGE, 2009). In this study the Aqua system provided in average 1.9 kg of lettuce for kg^{-1} of fish and the Aqua-BF system 2.6 kg of lettuce for kg^{-1} of fish. It indicated that Aqua-BF was more efficient than the other systems even with no significant difference between the variables evaluated in this study to Aqua and Aqua-BF. Accordingly, it should be taken into account that nutrients to plants are supplied daily from the feed offered to the fish, and the addition of biofloc improves the system. Aqua-BF eliminates the need for water exchange and an additional biofilter, commonly seen in traditional aquaponics systems, and without adding chemical fertilizers, as customary in hydroponics systems.

CONCLUSIONS

Under the conditions of this study, it was possible to conclude that aquaponic farmers can use silver catfish and aquaponic systems with and without bioflocs to improve the lettuce produce. The use of biofloc in the aquaponic system may improve the productivity but needs a better study to optimize and simplify this technology.

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