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Analysis of the Productive Capacity of an Aquaponic System with Macrobrachium Amazonicum (Heller, 1862) and Lettuce Culture (Lactuta Sativa Var. Crispa)

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Abstract: ***Aquaculture is one of the activities that depend on integrally of availability of water to be developed, both in quantity and quality. The present work aimed to realize one study in the productive capacity of the aquaponic system using farm shrimp (M. amazonicum Heller) with the development olive tree of Lactuta sativa specie. The method used was the experimental one, performing analyzes on physicochemical water parameters: Dissolved Oxygen (DO), pH, Electrical Conductivity (EC), Temperature, Turbidity (Tb), Ammonia, Nitrate, and Total Phosphor). The data analyzed indicated that there was one increment of biomass satisfactory (0,25 g to 0,878 g). Concerning water quality, it was noticed that dissolved oxygen and total phosphor were the only parameters that were outside the normative standards (4,59 mg/L and 2,91 mg/L, respectively), therefore, below of standard indicated for the National Environmental Council 357/05 (>5 mg/L and ≤ 0,03 mg/L, respectively). About parameters for farming shrimp, DO (4,59 mg/L), pH (5.84), ammonia (3,07 mg/L) and total phosphorus (2,91 mg/L) were prone to abnormality, therefore, non-standard (>5 mg/L;7,4 to 8,4; ≤1,6 mg/L; <0,5 mg/L, respectively). Regarding the development of L. sativa var. crispa, six individuals were analyzed, of which 1 presented better development than the others. Thus, aquaponic can provide good water quality from both a zootechnical, environmental, and hydroponic point of view.***

Keywords: Aquaculture, filtration, biomass

1. Introduction

The aquaponic system suffers impacts on water quality, and this makes it less productive. The variables contributing to these impacts are internal, that is, the high amount of organic matter and nutrients derived mainly from feed and excreta residues of the captive cultivated population [1].

The genesis of these nutrients has a fundamental milestone. Digestibility of the dry matter of rations, which is around 70 to 75%, 25 to 30% of the feed supplied enters the aquaculture systems as fecal material [2]. These effluents become rich in nitrogen and phosphorus and contribute to the eutrophication of the receiving water bodies, in addition to causing reduction or alteration of biodiversity. These circumstances not only cause pollution, but also directly harm aquatic communities, and often bring damage to other activities that would benefit these waters [3].

About aquaculture, [4], defines it as the culture of organisms (animals and plants) that have in marine, brackish, or freshwater their primary habitat and covers strictly aquatic and amphibian beings. That among the various branches of aquaculture, the most practiced is oyster farming (oyster farming), fish farming (fish farming), frog farming (ranching), and shrimp farming (carciniculture) [5].

Several beneficial factors for aquaculture, among which is integration with the agricultural crop system. In this case, carciniculture integrated to vegetable cultivation, as shrimp nursery effluents can be used to water and fertilize vegetables which, after filtering via the rhizosphere, return a better-quality effluent to the pond [6]. This whole process is called "aquaponics," and several vegetables that can be developed with this technology: lettuce, watercress, beet, rocket, among others [7].

However, each plant has a specific nutritional need. In this sense, the need to add nutrients in the system for plant development will depend on the species of plant, and its stage. As an example, he wrote that, unlike lettuce (Lactuta sativa), which has a low nutritional need, tomato (Licopercium sp.) might need dietary supplementation, especially P and K with mineral fertilizers [8].

But if this water is not passed on to an integrating system but discarded in a water body. It can cause impacts whose magnitude depends on many factors, such as the location of the farms of carciniculture; site of the construction of the tanks; management of the nurseries; use of technologies during operations in the plantations; type of cultivation; the scale of production and capacity of assimilation of the system; hydrodynamics of the recipient bodies, among others [9].

To carry out the reuse of effluents, and avoid disposal in water bodies, aquaponic systems include (1) mechanisms to remove solid particles from water that is composed of feces, uneaten feed and bacterial flakes, (2) nitrifying biofilters to oxidize ammonia ($NH3$) excreted by the animals, (3) oxygenating mechanisms to remove dissolved carbon dioxide ($CO2$) expelled by the animals and add oxygen to them and nitrifying bacteria [10].

Thus, this research deals with real and current problems, in addition to bringing more data on the construction and operation of aquaponic systems that can contribute to the mitigation of impacts from aquaculture effluents.

With this, the objective of this research was elaborated, which is the construction, analysis of the functioning of an aquaponic system: (1) verify the zootechnical performance of the biomass and survival of shrimps; (2) analyze the development of the Lactuta sativa var. crispa olericulture in the 49 days of culture; (3) monitor the quality of the water in the aquaponic system to verify which are in ideal conditions for the cultivation of the M. Amazonicum, and (4) identify, among the water parameters analyzed, which comply with environmental regulations, if released into the water body.

2. Material and Methods

2.1 physiography of the municipality

The municipality of Paragominas is in the southeast of the state of Pará, 320 km from the capital, Belém. It has a tropical climate with hydrography determined by the rivers Uraim and Igarapé Paragominas, also called Prainha igarapé. The vegetation is composed of submontane dense forest, dense lowland forest, and dense alluvial forest [11].

2.2 Study area

The study area (Figure 1) is in the municipality of Paragominas - PA, which has an area of 19,342.25 km² and an estimated population of 111,764 inhabitants [12].

Figure 1: Location map of the experiment. Paragominas - PA.

The experiment was developed at the University of the State of Pará, *Campus* VI, with coordinates S 02º59'07.2"; W 47º21'31.9".

2.3 Method

The research was carried out with an experimental procedure [13] it can be developed in the laboratory and the field. In this case, the Environmental Quality Laboratory (LQA) was used, and the outer part of the LQA, that is, in the area, because the system was posted on the right side. For textual composition and discussion of the data obtained, a survey of documentary data was carried out whose temporal cutout was from 2006 to 2019, in addition to pioneering literature.

3. Aquaponic System

3.1 Construction

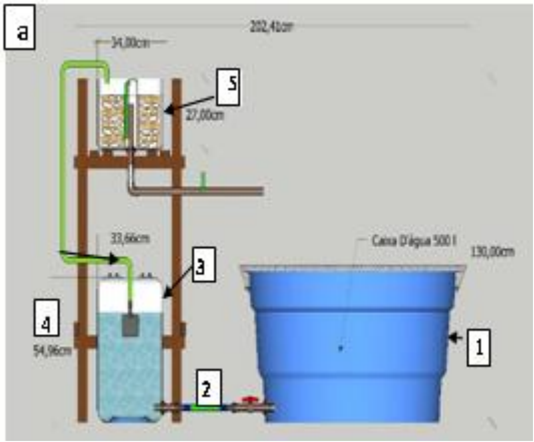
The system was built with two modules: (1) a cultivation tank with the use of a Polyacrylate Vinyl (PVC) water tank, with a volume of 500L, but it was filled with 400L; (2) a biofilter, with the use of 50L canisters, one for the decanter, and the other to which the lateral part was removed, and expanded clay was placed for water filtration and fixation of the oleric.

The choice of this type of clay is justified because of Silva et al. (2013) state that it minimizes the problem of clogging the system and increases its treatment capacity because it has high porosity and high specific surface area, which allows better adhesion of bacterial biofilm.

3.2 Functioning

The system works as follows: the effluent is released from the culture tank

1) It supports through a connection at the bottom of the container;
2) to the decanter filter;
3) where preliminary filtration takes place, to remove coarse solids. With the help of a 20W pump;
4) the effluent is sent from the decanter to the expanded clay biofilter;
5) where the selected species is fixed and, after reaching the flow level, it is sent back to the culture tank (Figure 2).



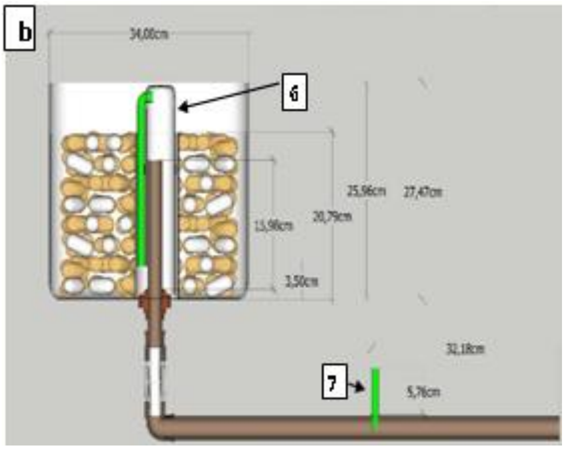


Figure 2: a) lateral view of the system; b) cross-section cut of the biofilter and aerator.

Legend: 1-crop tank; 2-outlet from tank to decanter; 3-decanter; 4- submerged pump; 5-biofilter; 6-syphon; 7-oxygenator.

The perform the water flow from the biofilter and its oxygenation, a siphon (6) and a Venturi oxygenator (7) were installed. The siphon is composed of three Polyacrylate Vinyl (PVC) pipes with diameters of 75 mm, 50 mm, and 25 mm. At the same time, the oxygenator was made of a hose and had approximately 11 mm in diameter).

3.3 Choice and acquisition of the shrimp and the oleric

The choice of the species Macrobrachium amazonicum (Heller,1863) whose vernacular name is "Amazonian shrimp" or "regional shrimp," is justified by the aspects it has and that was observed in the research [14]: easy maintenance and reproduction in captivity, high fecundity, fast growth, low and straightforward cost feeding, rusticity and good acceptance in the consumer market.

For all these reasons, they wrote that the species is the main shrimp exploited by artisanal fishing in the Amazon and figures as one of the most promising species in the world for cultivation in inland waters. Regarding the acquisition of the juveniles of M. amazonicum, they were obtained in the Laboratory of the Federal University of Pará (UFPA), Campus Bragança. One hundred fifty minors (Dbio = 250 ± 3.7 mg) of this species were ceded.

As for olericulture, the species Lactuca sativa var. crispa was chosen. This choice is justified due to the low nutritional requirements of this species [15] and the excellent acceptance in the consumer market [16].

3.4 Containment and germination

The 150 individuals were removed from the expanded polystyrene (Styrofoam) container with a capacity of 50L and transplanted into the culture tank. The initial density was 150 cams. /m², as the bottom area of the water tank, is equivalent to 1 m^2. About the olerícola, her germination process occurred on 28/08, with the use of a germination tray, inside which three to six seeds were placed. On September 27, after 30 days of germination, the six individuals that developed best were selected. Then, the transplant to the cultivation module of the system was performed.

3.5 Monitoring

3.5.1 Nutrition and biomass growth

For shrimp nutrition, the one recommended [17], i.e., daily an amount equal to the average of 10% of the total biomass present in the pond was made available, divided between morning and afternoon. The feed used was pelletized, marked Polynutri, with particle diameter between 2.0 mm and 2.4 mm, to maintain high stability in water. About the feed, it contained 35% pure protein and other nutrients (Table 1).

Table 1: Nutritional characteristics of the feed used in the experiment. Paragominas -PA.

	U.	Valor's	
Nutrients		Mín.	Máx.
Animal protein		350	-----
Humidity		-----	130
Ether extract (mín.)		65	-----
Fibrpus matter (máx.)	g/kg	-----	50
Mineral matter (máx.)		125	-----
Cálcium (mín.-máx.)		18-28	-----
Fósforum (mín.)		13	-----
Vitamin E (min.)	UI/kg	150	-----
Vitamin C (máx.)	mg/kg	150	-----
Selenium (mín.)		0,2	-----

Legends: U -Unit; Mín. – Mínimum. Máx. – Máximum.

The feeding took place at two times during the day: (1) in the morning, 09:30 hours; (2) in the afternoon, 16:30 hours, as recommended by Lima et al. (2019), in a research carried out at the Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA), Macapá - AP.

About biomass gain, the methodology used was adapted through accurate data described in [19]. It used a sampling of 3% of the total individuals in captivity, weighed every 30 days. To increase the representativity of the work sample in Paragominas, a sampling of 7% of individuals in detention, considered (Shimadzu precision scale AY220), every ten days was performed. To better understand the biomass gain in this experiment, we identified the initial (Pi) and final (Pf) weights.

The perform the water flow from the biofilter, and its oxygenation, a siphon (6), and a Venturi oxygenator (7) were installed. The siphon is composed of three Polyacrylate Vinyl (PVC) pipes with diameters of 75 mm, 50 mm, and 25 mm. At the same time, the oxygenator was made of a hose and had approximately 11 mm in diameter).

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Nutrients	U.	Values	
		Mín.	Máx
Animal protein		3.50	-----
Humidity		-----	130
Ether extract (mín.)		65	-----
Fibrpus matter (máx.)	g/kg	-----	50
Mineral matter (máx.)		125	-----
Calcium (mín.-máx.)		18-28	-----
Fósforum (mín.)		13	-----
Vitamin E (min.)	UI/kg	150	-----
Vitamin C (máx.)	mg/kg	150	-----
Selenium (mín.)		0,2	-----

Legends: U -Unit; Mín. – Mínimum. Máx. – Máximum.

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3.7.2 Survival

Regarding survival, Equation 1 was used [19].

$$Sf = \frac{Nf}{Ni} \quad (1)$$

Source: [18].

Where: SF = ultimate survival; Nf = Numbers of individuals alive at the end of the experiment; Ni = Numbers of individuals initially placed in the tank.

3.7.3 Development of the Olericulture

For the verification of the olerícola, the method used [20] was adopted, which studied the productivity of individuals with curly lettuce for purposes commercial, and analyzed the following parameters: plant height, plant diameter, and numbers of leaves, stem diameter, stem length, total and retail fresh mass, and percentage of dry weight. For the research in Paragominas, this method was adopted due to the absence of sufficient individuals to encompass a representative statistic and the use of necessary characteristics to evidence the development of the plant was made (Table 2).

Table 2: Parameters analyzed.

Analyzed Characteristics	Measurement method	Units
Plant height (H)	Measured from ground level to the top of the plant with the aid of a graduated ruler.	cm
Plant width (Pw)	Performed on the edges of the plant with the aid of a 50 cm/mm graduated ruler.	cm
Numbers of leaves (Nl)	All the leaves were accounted for, including the new ones.	unit
Stem diameter (Sd)	Conducted with the aid of a Messen-IP54 brand digital pachymeter.	mm
Total fresh mass (Tfm)	It was made with the aid of a Shimadzu AY220 precision scale.	g

Adapted from [20].

3.8 Water parameters

The selection of water parameters was based on the importance of aquaculture development, with emphasis on M. amazonicum culture; and water quality, to verify how much effluents can harm water bodies. Also, the feasibility and costs of analyses were considered (Table 3).

Table 3: Description of parameters and methods used.

Parâmeters and Units	Collection Periods	Methods	Place of analysis
DO (mg/L) [14]-21]- [22]-23]		Probe	In loco
Tb (NTU) [22]		Photometry	Environmental
Ec (µS) [23]	Alternate s	Probe (*in loco*)	

T (°C)[14]; [21]-[23]		Probe	*In loco*
pH[14]; [21]-[23]		Probe	
P-total (mg/L) [22]	Every five days	HACH 8029	Tower
NH_3(mg/L) [14]; [21]-[23]		HACH 8038	
NO_3 (mg/L) [22]-[2 3].		SM22 Método 4500	

Legends: [14]- [21]-[23].

All collections were made at 10:30, one hour after the shrimps were fed, according to [19]. For water collection and conservation of samples, the methods established by the National Foundation Health [24]. To improve the homogeneity of water samples to analyze their quality, they were collected by integrating water from the bottom, middle, and surface of the tank [25]. It is worth noting that the sample for analysis of ammonia, nitrate, and total phosphorus of the 25th day of the experiment was unusable due to an incident during transport.

3.9 Disuniformity in the System

On the 19th day of the experiment, there was a leak and, consequently, a shrimp escape, which decreased the number from 150 to 83 individuals (Density = 83 cams ./m²), thus remaining at this same density until the end of the experiment. This fact interfered in two ways with the System: (1) positively, because it was necessary to add 230 L of water so that the experiment could be continued; and (2) negatively, because it interfered with the productivity of the System because it reduced the number of individuals. Therefore, the biomass calculation was adjusted, and it was carried out in two stages: the first with 19 days and the second with 30 days, which totaled 49 days.

3.10 Statistical Treatment of Data

The arithmetic means, standard deviation, and Pearson Correlation was used to treat the data to identify correlations between water quality parameters. The Excel software, Version 2016 [26], was the tool used to perform these calculations, as well as data tabulation and preparation of graphs and tables, as recommended by the Brazilian Institute of Geography and Statistics [27]. The Coefficient of Determination (R²) was used, which varies from 0 to 1. The closer to 0, the less significant are the correlations, which indicates that other variables influence the Analyzed parameters. The closer to 1, the correlations present more significance, which shows that the settings exert more influence among themselves [28]. For Pearson Correlation, the values of r, in the correlation between the variable Hydrogen ionic potential x Dissolved oxygen; pH x Electric Current; Dissolved Oxygen x biomass were adapted from [29], for their characterization (Table 4).

Table 4: Values used for *r*.

Values	Caracterization of correlation	Relation
0	There is not	Não há
0,10 a 0,30	Weak	Direct
-0,10 a -0,30	Weak	Inverse
0,40 a 0,60	Average	Direct
-0,40 a -0,60	Average	Inverse
0,70 a 1,00	Strong	Direct
-0,70 a -1,00	Strong	Inverse

Adapted from the data contained in [29].

4. Results and Discussion

4.1 Shrimp Biomass Performance

During the analyzed period, a total of 489.86 g of feed was administered, which increased the average weight of individuals by 0.628 g (351%), and raised the total biomass from 37.5 g to 53.4 g (before does uniformity), and from 39.2 g to 72.8 g in the last 30 days (Figure 3).

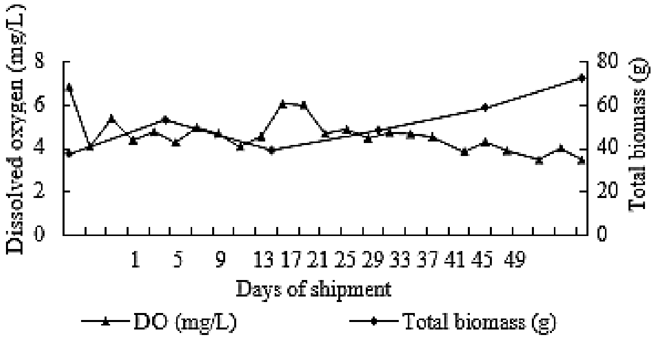

Figure 3: Variation of total biomass compared to dissolved oxygen.

The analysis of the data obtained for the two nutritional stages indicated that: in the first (at 19 days) there was an increase in shrimp weight of 0.223 g (Pi = 0.25 g; Pf = 0.473 g) with the supply of 181.68 g of feed; in the second (in the following 30 days) the biomass increase was 0.405 g (Pi = 0.473 g; Pf = 0.878 g) with the supply of 308.18 g (+ 126.50 g). At the end of the 49 days, the weight of shrimps rose from 0.250 g to 0.878 g (Table 5).

Table 5: Parameters used to evaluate shrimp performance.

Parâmeters	Standards recommended by literature on carciniculture	Average analyzed
pH	7,4ª 8,4[21];[23]	5,84 ± 0,71
EC (mS)	< 1 [22]	0,233 ± 0,02
T ºC	28 a 30 [21]	28,15 ± 1,44
Tb (NTU)	< 50 [22]	2,35 ± 0,68
DO (mg/L)	>5 [21]	4,59 ± 0,8
NH_3 (mg/L)	≤ 1,6 [21]	3,07 ± 1,28
NO_3 (mg/L)	< 80 [21	6,53 ± 4,74
P-total (mg/L)	< 0,5 [22]	2,91 ± 1,33

Days	Numbers of people	Quantity of feed (g)	Total biomass (g)	Unit weight of individuals (g)
1	150	3,75	37,5	0,25±3,7
10	150	5,34	53,4	0,356±4,2
20	83	3,9259	39,259	0,473±3,6
30	83	4,8638	48,638	0,586±2,9
40	83	5,893	58,93	0,71±4,1
49	83	7,2874	72,874	0,878±4,3

The second stage provided a more appropriate development for the shrimps than the first stage, before the disuniformity. This can be justified in two ways: (1) the decrease in optional density caused by the "escape" of 67 individuals, which allowed more dissolved oxygen to be available for the shrimps, and improved their development, and (2) the nutritional enhancement offered to the shrimps according to the biomass gain. This fact corroborates the data obtained by [30], which states that few species respond well to densification, and it is necessary to increase investments to mensure proper water quality in ponds with high population density.

In Macapá - AP, [18] research at the EMBRAPA Research Laboratory, and the data they obtained indicated a biomass gain of 1.4 g (Pi = 0.314 g; Pf = 1.72 g) during 120 days of experiments carried out in an aquaponic system with a density of 80 cam./m².

For comparison purposes, due to the different experimental periods in the two surveys, the daily average biomass gain was calculated, which in Macapá was 0.011 g/day, and was 0.012 g/day. The slightly higher value may be due to the younger animals in Paragominas, and the younger the shrimp, the higher the biomass gain, which decreases as the total biomass of the shrimp increases.

4.2 Overview

The analysis of the obtained data indicated survival of 55.33%; that is, the final density was 83 cams. /m². The reduced survival values found in the Paragominas research are a result of the disuniformity that occurred during the experiment, which led to a reduction in population density. Thus, if the incident did not happen, it would be possible to increase this survival.

In this sense, research conducted in Macapá, near EMBRAPA, [18] indicated at the end of the experiment, the survival of 76.3% for the density of 80 cams. /m² in an aquaponic system using the species M. amazonicum.

4.3.2 Water analysis in Carciniculture

Regarding the recommended standards for carciniculture, the analyses indicated that the values obtained for dissolved oxygen (justified in the previous item), pH, Ammonia, and Total Phosphorus were outside the established ranges (Table 6).

Table 6: Description of the mean of the parameters analyzed in the study and their own recommended standards in the literature.

The average pH value (analyzed value = 5.84) indicated a slight acidity in the medium, although in some days, there was a tendency towards alkalinity (maximum amount = 7.3). These values are related to the addition of nutrients (nitrogen and phosphorus, for example) from feed and excreta. Also, the non-mineralization of these nutrients due to the low concentration of dissolved oxygen may have influenced it. According to studies [21], the ideal pH for the cultivation of M. amazonicum should be between 7.4 and 8.4.

On ammonia (analyzed value = 3.07 mg/L), it was above the recommended value [21] for the cultivation of M. amazonicum (indicated value = ≤1,6 mg/L).

However, it was not possible to notice any damage to the development of individuals. Nitrogenous compounds such as ammonia are results of organic matter from feed waste and shrimp excreta, and the high values in this research may be related to the low concentration of dissolved oxygen in the tank, insufficient to mineralize the nutrient. This fact corroborates the literature [43], which states that there is an increase in ammonia in environments with low levels of dissolved oxygen.

Regarding Total Phosphorus (analyzed value = 2.91 mg/L), the values measured in this research were outside the standards recommended [22] for the culture of organisms in aquaculture (indicated value < 0.5). May be related to the difficulty of filtering phosphorus in the environment, as well as, due to the slightly acidic environment.

This fact corroborates the study carried out [34] in a survey conducted in Tucson - the USA, where they state that the availability of phosphorus and pH are quantities that behave inversely in aquaponic systems, so the low pH values found in the Paragominas survey may have influenced the high values analyzed for Total Phosphorus.

4.4 Water Parameters of Aquaponic

The analysis of the data obtained indicated that the pH value was between 5.23 and 7.3 (x = 5.84), i.e., a tendency to acidity in the period analyzed. Regarding the effect of the incident on the pH, the addition of water caused the salts present in the effluent to be diluted. However, the slightly acid nature of the source water promoted a reduction in the value of this parameter in the period immediately after the incident, which occurred on day 19 (Figure 4).

Figure 4: Hydrogen ionic potential behavior

On this variable, studies involving M. amazonicum in aquaponic, and carried out [18] in the municipality of Macapá - AP, concluded that the waters of the culture present a tendency to slight alkalinity (x=7.59), while [21] state that the ideal pH for the development of this species is around 8.

However, [34] affirm that in aquaponic systems, it is recommended to keep the pH between 5.5 and 7.2, so that the plants have proper development. Therefore, the pH values measured in the Paragominas survey were within the standards recommended by this author for aquaponic.

In the analyzed data, it was also noticed that after the 29th day, the pH value decreased sharply, which can be a consequence of a low concentration of dissolved oxygen offered for aerobic bacteria to mineralize the nutrients present in the water. This influence, the correlation between Hydrogen ionic potential x dissolved oxygen, was made (Figure 5).

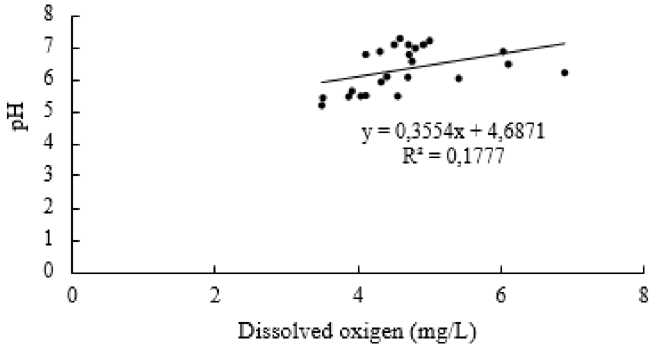

Figure 5: Correlation between pH x OD

The value of the Pearson coefficient (r = 0.42) indicated that there is a correlation between them of medium and direct degree but little significant (R^2 = 0.17). Therefore, it is proved that more factors influence the relation between pH and dissolved oxygen, for example, the addition of allochthonous in organic matter.

About this influence [14] researched Itaquatiara, AM, at the agro-industrial farm Tambaqui Ltda, and [35] in China, in the city of Jinan, and stated that in acidic environments (i.e., pH < 7), concentrations of dissolved oxygen can be reduced due to mineralization of compounds such as ammonia, which help confer an acidic texture to the environment, so the attention of this nutrient in research in Paragominas (x = 3.07 mg/L), may also have influenced the low levels of dissolved oxygen and pH.

About the electric current, the data obtained and analyzed indicated average values between 0.186 to 0.280 mS/cm² (x = 0.233 mS/cm²), with a tendency to rise sharply after the first 13 days. As for the influence of the incident on this parameter, it can be observed that in the period immediately after the fact, there was a drop in electric current values, which indicated that the ions present in the effluent were diluted by the addition of water (Figure 6).

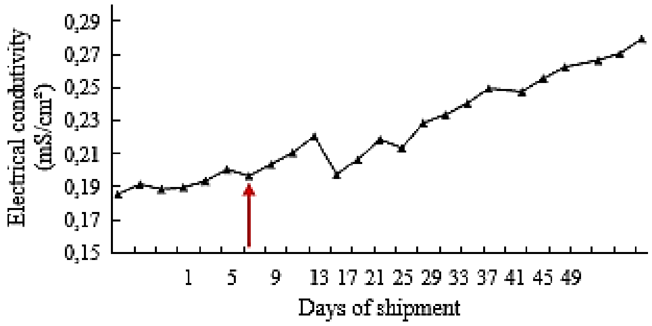

Figure 6: Behavior of the EC

About this behavior [18] found an electric current variation of 0.115 to 0.225 mS/cm² in an aquaponic system with M. amazonicum and [36] in research in the city of Macapá - AP, described a variation of 0.079 to 0.475 mS/cm² in a recirculation system coupled to a biological filter.

The study carried out [37] in Dourados, MS, concluded that there was a variation from 0.07 to 4.3 mS/cm²; the author states that the high electric current values in aquaponic systems are due to low water renewal, but with continuous recirculation, it becomes satisfactory for plant development, which justifies Paragominas research since the recirculation occurred consistently and the reoxygenation and fertilization of plants.

In the data analyzed, it was also perceived that electric current values might be related to pH, since both parameters vary depending on the presence of salts in the water [38]-[39]. Then the Pearson test was performed for these variables (Figure 7).

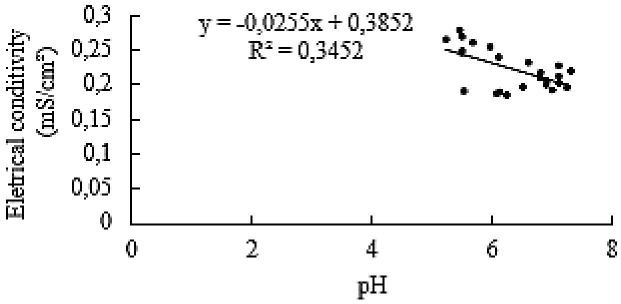

Figure 7 – Correlation between EC x pH.

After the analysis, it was verified that both are correlated, in medium degree and the inverse form (r = -0.58), that is, if one presents tendency of elevation or decrease, the other will give the inverse; however, the analysis of the determination coefficient indicated that there is little significance in this correlation (R^2 = 0.34), that is, other variables are influencing in the values of these parameters, but that did not object of this research.

Regarding this relationship,[18] states that due to the electric current being linked to the number of salts in water, in acidic environments, the values are expected to be high. This argument corroborates Paragominas research, as there was an upward trend in her tendencies, while the effluent had an acid pH (x = 5.84).

As for temperature, the analysis of the data obtained indicated that there was a tendency to vary between 26.7 ºC and 29.7 ºC on the hottest day (43º day). Thus, the value of the average was equivalent to 28.05 ºC. Up to the 11th day, there was a tendency to decrease the costs measured. In the last six days, the behavior of this parameter showed stabilization with a slight upward trend at the end of the experiment. Regarding the increase of water due to the incident, it was noted that in the following measurement the temperature presented a low value (27.3 ºC on day 21), however, until the 49th day of the experiment, there were days when the temperature was even lower (27.2 ºC on day 27), which may indicate that more factors, besides the increase of water, may have caused this trend, such as the local microclimate (Figure 8).

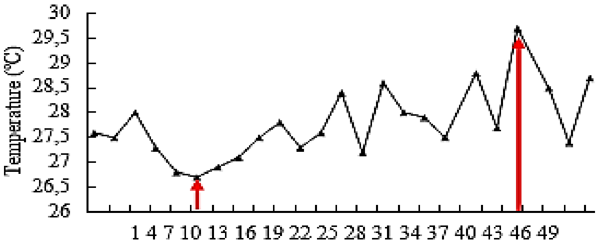

Figure 8: Behavior of temperature

Regarding temperature variations [18] in a study conducted in Macapá - AP, concluded that the values for this variable remained between 27.2 and 31 ºC. These values are conducive to the development of M. amazonicum, as they are close to what [23] identified in natural environments for the species, which was between 27.5 and 31ºC, and close to what [21] indicate for excellent productivity in this type of crop (28 to 30 ºC). However, [40] states that the ideal temperature for growing lettuce is 24ºC. Therefore, the values measured in Paragominas are out of the recommended for this crop, but even so, there has been the development of the plant. As for turbidity, the data obtained and analyzed indicated that there was an upward trend. When compared with the source water (0.02 NTU), there was an elevation to 4.69 NTU (+ 4.49 NTU) at the end of the 49 days of the experiment. On the increase of water after the incident, this caused the dilution of sediments that influence the turbidity, which generated a small reduction in the values of this parameter (from 3.14 NTU to 2.46 NTU), observed from the 19th day (Figure 9).

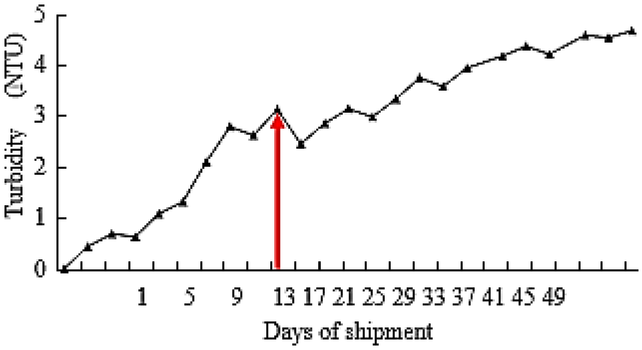

Figure 9: Behavior of Turbidity

In the research in Macapá, AP, [36] found values for turbidity ranging from 0 to 9 NTU for the cultivation of M. amazonicum in a recirculation system coupled to a biofilter. In contrast, in the study [18], also conducted in Macapá, AP, there was an indication of turbidity variation from 0.5 to 4.5 NTU, for the cultivation of M. amazonicum in aquaponic. The research in Paragominas also showed an upward trend during cultivation, which corroborates the literature of the cited authors.

Regarding dissolved oxygen, it varied from 6.89 mg/L in the source water to 3.49 mg/L at the end of the analyzed period and showed a tendency to decrease during the experiment. Regarding the effect of the increase of water in this parameter, it is observed that there was a considerable increase in its value (from 4.58 mg/L to 6.1 mg/L), motivated by the high concentration of dissolved oxygen in the source water, which consequently increased the level of the parameter in the tank (Figure 10).

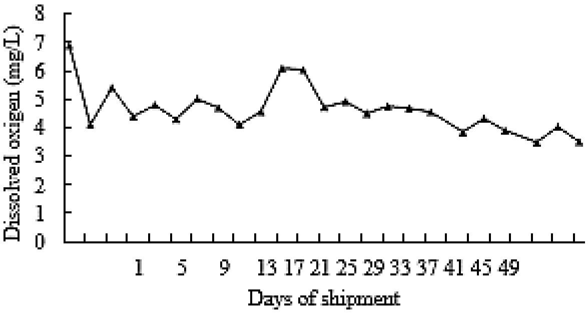

Figure 10: Behavior of DO.

After the analysis, it was found that, for dissolved oxygen, about M. amazonicum, the value obtained (x = 4.59 mg/L) is close to the minimum seen by [27] in natural environments (4.6 to 6.1 mg/L) and below the recommended [21] for the cultivation of M. amazonicum (>5 mg/L).

The primary justification may be the type of aerator used in this work, which by dispensing with the use of electric energy, may have presented lower efficiency than the electric aerators, commonly used in aquaponics. This fact corroborates the research [41], who states that in intensive crops, natural aeration is not able to supply the need for dissolved oxygen of beings living in that System.

Regarding the values for dissolved oxygen, in the studies with aquaponic carried out [18]-[35] used electric aerators and obtained benefits between 5 mg/L and 7.27 mg/L, i.e., higher than those measured in Paragominas, which confirms the argument.

In this sense, the drop in dissolved oxygen is also related to the accumulation of organic matter from the feed, because the population density was reduced (from 150 individuals to 83 individuals) due to the leakage and escape of shrimps, which consequently reduced the total consumption of dissolved oxygen from the animal metabolism. Another factor that may have influenced the decrease of dissolved oxygen was the use of a 50% shading over the tank, to avoid predation by birds, which reduced the solar radiation and, consequently, the primary production within the captivity.

However, after the 40th day, there was a sharper reduction in dissolved oxygen levels, which may be related to the gain of biomass by shrimps, which increases the consumption of this parameter. After the analysis, it was noticed that the variables present a strong. Inverse correlation (r = - 0.9), however, there is no significance in this, since the determination coefficient found was practically null (R^2 = 0.06), which indicates that in this research biomass did not interfere directly in the consumption (by respiration) of dissolved demand biomass (Figure 11).

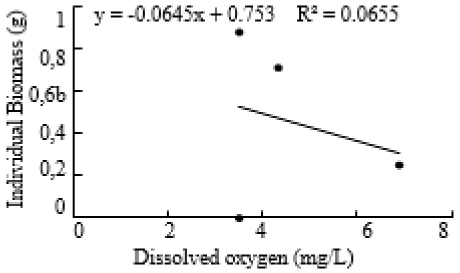

Figure 11: Correlation between individual shrimp biomass and dissolved oxigen

Nevertheless, the population density was also a factor in the decrease of dissolved oxygen in terms of increased organic matter in the tank (feed and excreta). The study corroborates this carried out [3], who state that population density decreases the levels of dissolved oxygen considerably, and suggest that in cultivation without aeration, or with poor ventilation, a reduction in population density occurs.

Regarding ammonia, this parameter presented significant variation along the analyzed period, with an average of 3.07 mg/L. After 30 days, there was a tendency of reduction, which may have been motivated by the population reduction in the tank and by nutrient filtration (Figure 12).

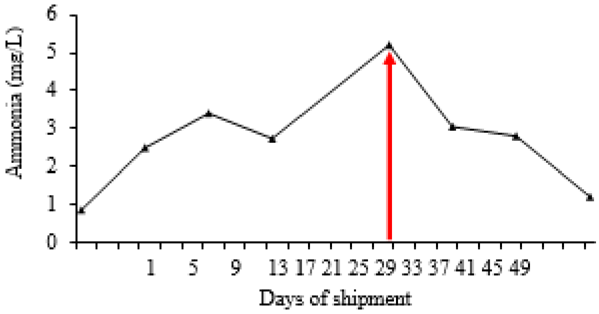

Figure 12: Behavior of the Ammoniacal nitrogen behavior

It is noted that during most of the experiment, the value of ammonia was above that recommended [21] for the cultivation of M. amazonicum (≤1,6 mg/L). The peak of this parameter occurred on the 30th day of the experiment (5.21 mg/L). It may have been the result of a sudden failure in the filtering process, (caused by negligence in the evacuation system) because the reduction of the values at the end of the experiment indicates that the biofilter was in operation and that it would be possible to keep the shrimps in these conditions for a long time without significant damage to their development.

In the research conducted in Paragominas, in the period when the pH begins to reduce, ammonia also decreases, which may indicate more excellent absorption of this nutrient by the plants, resulting from its filtration as corroborates the data obtained [35], which states that an acid pH, there can be a reduction in ammonia values due to more excellent absorption by plants.

To better evaluate the value obtained, it was compared with values obtained in the research [18] and [36]. In the first, the mean value was 0.5 mg/L, and in the second, it was <1 mg/L. This difference about the value in Paragominas may be the result of the use of electric aerators, which allow a higher concentration of dissolved oxygen and the consequent mineralization of ammonia, which corroborates the literature [42].

Regarding nitrate, the data analyzed indicated a mean value of 6.53 mg/L. This parameter showed considerable variation throughout the experiment and finished the 49 days with an upward trend (11.07 mg/L) to its initial value (2.5 mg/L). Its mean value was 6.53 mg/L (Figure 13).

Figure 13: Nitrate behavior

The values analyzed for nitrate remained within the recommended range for the cultivation of M. amazonicum, which is < 80 mg/L, as supported [21]. Initially (until the 8th day), the value of this parameter did not change, which is expected due to the non-stabilization of the biofilter, which usually occurs in the second week of cultivation.

Similar behavior was observed [18], who found the nitrate levels in his research increase from the 10th day (x= 18.04 mg/L). In this sense, the lower values in the study in Paragominas (x = 6.53 mg/L) may be justified due to acid pH, which inhibits nitrification of ammonia in nitrate this corroborates the research [35], who found inhibition of microbial action to mineralize ammonia in nitrate, at pH equal to 6.

As for Total Phosphorus, the analysis of the data obtained indicated a tendency to rise until the 19th day. After this period, there was a tendency to reduce until the 42nd day, and then an elevation occurred again (Figure 14).

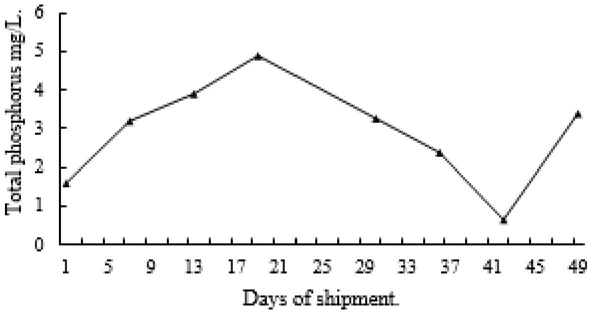

Figure 14: Total phosphorus behavior

Regarding the mean value of Total Phosphorus [22] in the study carried out in Jaguariúna (SP), recommend amounts < 0.5 mg/L for this type of crop. In Paragominas, the value analyzed (x = 2.91 mg/L) was higher than recommended, which may suggest that the biofilter had difficulties in removing phosphorus from the medium because in the study [1] it was found that phosphorus is the nutrient that presents more problem to be removed in treatment systems.

In the study conducted in Tucson (USA), [34] in aquaponic systems, phosphorus is more available in acid environments. The research corroborates this statement in Paragominas, as high values of total phosphorus (2.91 mg/L) were found concerning acid pH (5.84).

In this sense, it is worth noting that these last three parameters (ammonia, nitrate, and total phosphorus) regularly interact inside the culture tank, and all contribute to the reduction of dissolved oxygen and pH. The vapor comes from the decomposition of the organic matter, besides being the main element released in shrimp excreta, phosphorus is mainly concentrated in the residues not consumed from the feed. The excess of these nutrients in the culture tanks makes the environment acidic, besides consuming the dissolved oxygen due to mineralization promoted by bacteria, which can make the insufficient for the full development of the animals [1]. On the other hand, in acid pH, there is inhibition of nitrification of ammonia in nitrate [35], which makes it difficult to remove this nutrient (ammonia) from the medium, and can damage the development of the animals, due to their toxicity. However, the acid pH promotes better development for plants in the aquaponic system.

5. Development of L. sativa var. crispa

The data obtained and analyzed for the development of individuals of the species L. sativum var. crispa indicated that one of them showed a tendency to grow (Table 8).

Table 8: Analysis of the development of olerícolas.

I	H (cm)	PW (cm)	NL (unit)	SD (mm)	TFM (g)
1	31,1	33,7	22	25,2	377
2	21,7	28,2	16	26,8	234,1
3	19,2	23,5	19	17,1	204,5
4	20,3	22,9	19	18,3	210,6
5	18,9	21,2	17	17,1	185
6	12,2	14,3	9	14,3	114,1
Av	20,5	23,9	17	19,8	220,8

Legends: I – Individuals; A. v- Average values; H - plant height; LP - plant width; NF - number of leaves; DC - stem diameter; MFT - total fresh mass.

The development of the olerícola showed little homogeneity, and only individual 1 showed full growth in all parameters. Individual 2 also showed significant progress, however, after the 13th day of the transplant, a part of his stem was broken due to the action of the wind, which reduced the final data of his development (H and NF, mainly). Individual number 6 was the one who developed the least, so the values in all parameters were considerably lower when compared with the rest of the plants.

About this [18] found a mean value for the number of leaves (NC) equal to 16 in an aquaponic system with a density of 80 cams. /m². In Paragominas, the analyzed costs were higher, which can be justified by the reduction of the pH from the 29th day, which provided a better absorption of nutrients by the plants. In this sense, the pH value in the research in Paragominas is close to the ideal costs for cultivable plants (5.5-5.8), as stated [35] in a survey conducted in Jinan, China.

Despite their development, the young leaves showed a slight yellowing (Figure 15e), and the leaves generally withered during periods of siphon malfunction (Figure 15c).

Figure 15: a) day of the transplant; b) 13th day after operation; c) 26th day after transplant; d) 39th day after transplant; e) detail of young leaf (39th day); f) least developed individual (39th day).

Regarding wilting and yellowing of young leaves [43] stated that both symptoms might be due to Calcium (Ca) deficiency or Boron (B), however, wilting may also occur due to excess moisture. This last factor corroborates the research in Paragominas, as it was found that wilting was concurrent with the malfunctioning of the evacuation system.

In the study conducted [44] in the city of Leme, SP, the authors concluded that excess Nitrogen (N) and Potassium (K) could also cause yellowing or withering, so there is a need for further investigation to determine the real reason for symptoms in plants of the Paragominas survey.

Thus, nutrients were deficient in the lettuce culture in Paragominas, and this is corroborated by the study [18], who stated that the mineralization and transformation of nutrients from the M. amazonicum pond were not adequate to promote good productivity for lettuce within an aquaponic system.

6. Conclusion

The increase in biomass in shrimps was satisfactory. It can increase as water quality parameters (Dissolved oxygen, Hydrogen ionic potential, phosphorus, ammonia) are adjusted to the recommended values for optimal shrimp development. Survival was influenced by shrimp escape, which can be easily circumvented by daily monitoring.

The plants showed healthy development. In this sense, it is worth noting that more research needs to be done to improve the availability of nutrients for them.

It is worth mentioning that, although the initial investments are relatively lower for a domestic scale system, the intellectual capital needed to handle the System is high due to the complex relationships that occur within an aquaponic system and that influence its productivity.

Therefore, aquaponics can provide excellent water quality, both from a zootechnical, environmental and hydroponic point of view, and this relates to mechanisms for inserting dissolved oxygen into the water, the main limiting factor, and responsible for providing energy to mineralize nutrients from excreta and feed leftovers.

It is suggested the application of methodologies that test other aerators that dispense with the use of electric energy, including the method together with them, as a way to save on initial costs and increase productivity to make the technology even more accessible to people. It is also suggested the use of timers, or to reduce the relationship between the height and the base of the biofilter, to avoid problems with the functioning of the siphon, responsible for performing the evacuation of the effluent from the biofilter.

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