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Culture of *Melanochromis* sp. and *Lycopersicon esculentum* var. *Cerasifonne* in a combined system of Biofloc and aquaponics

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Abstract
The aim of this study was to make an aquaponic production system with the ornamental fish *Melanochrimis* sp. and tomato cherry, in a Biofloc system with different carbon sources. For fish and plants culture it was made a floating root system in Rotoplas ® water tanks of 250 L capacity, which were filled with 125 L of water and 100 juvenile fish. For each tank a 100 cm diameter Styrofoam plate was placed and 21 holes of 2" diameter were drilled to place a plastic basket with a cherry tomato plant. The survival in the four experimental treatments, was above 90%. Coffee and moringa treatments where the ones that presented higher gain values, with coffee the highest length gains in fish and plants were obtained with 11.61 and 54.67 cm, respectively. While moringa obtained the highest gain values for width and weight in fish with 2.16 cm and 7.13 g, respectively. With this, it can be proved that the viability of aquaponic systems at small scale, using a Biofloc system that allows to reduce the negative impact that aquaculture activity has on the environment.

Keywords: Cichlids, cherry tomato, aquaponics, Biofloc

1. Introduction
The industry of ornamental fish is a business with high perspectives of development in Mexico, where 711 farms operate and produce 66 million of organisms per year with production value of 120 million of pesos [1]. One hundred and sixty species and varieties are cultivated for various interests, within these species is the African cichlid (*Melanochromis* sp.). The ornamental fish trade in Mexico has grown by 250% during the last ten years [2].
In the last decade within the aquaculture sector, a series of production systems for the culture of diverse aquatic organisms have been developed, orientated to decrease the use of water and space, increasing considerably the culture density [3]. One of these technologies is the Biofloc system, which consists in the development of microbial floc formed by a relation of carbon-nitrogen in the water, with little or no water replacement (0.5 to 1% per day) [4], and high oxygenation [5,6], in which diets with low raw protein content are used [7] and also external carbon sources like molasses (sugar cane), rice bran, wheat bran [8], and Yucca, Moringa and Macroalgae flours [9]. These carbon sources allow the growth of a microbial community, mostly of heterotrophic bacteria that metabolize carbohydrates and take inorganic nitrogen resolving the saturation problems of nutrients from its recycling [10, 11].
On the other hand, aquaponics is the name given to the integration of aquaculture and hydroponics, that consists in fish and plant's culture in a close recirculation system. Aquaculture effluents provide most of the nutrients required by plants if it is maintained an optimum relation between food income and culture area of the plant [12].
Among the advantages of aquaponics, it's included: the prolonged water reuse and minimization of discharges. Also, the integration of the production systems of fish and plants allow cost savings with which profitability is improved in aquaculture systems [13].
That is why, the aim of this study is to make the aquaponics production system of ornamental fish *Melanochromis* sp. and plant cherry tomato (*Lycopersicon esculentuim* var. *cerasifonne*), through a Biofloc system with four different carbon sources: Coffee, Moringa, Macroalgae and Yucca.

2. Material and Methods

2.1 Seedling germination

Cherry tomato seeds were placed in plastic trays for its germination. Each seedbed was filled with peat of the company REKYVIA ®, which is enriched with nutrients to obtain a better germination. Trays were placed in a plastic shelf with LED lights, with a photoperiod of 12:12 hrs.

2.2 Experimental design

The experiment took place in the Live Food Production and Biofloc Laboratory in the Universidad Autónoma Metropolitana, Unidad Xochimilco. For fish and plants culture it was made a floating root system in Rotoplas ® water tanks of 250 L capacity (0.80 x 100 cm), which were filled with 125 L of water and 100 juvenile fish of *Melanochromis* sp. genus. It was placed with a LED light per tank, as well as an aeration system with the aim of a porous aerating stone of 25 cm of length, with the sufficient intensity to move all the water column, allowing that the food, carbon source and wastes move though all the water column. For each tank a 100 cm diameter Styrofoam plate was placed and 21 holes of 2" diameter were drilled to place a plastic basket with a cherry tomato plant (Fig. 1).

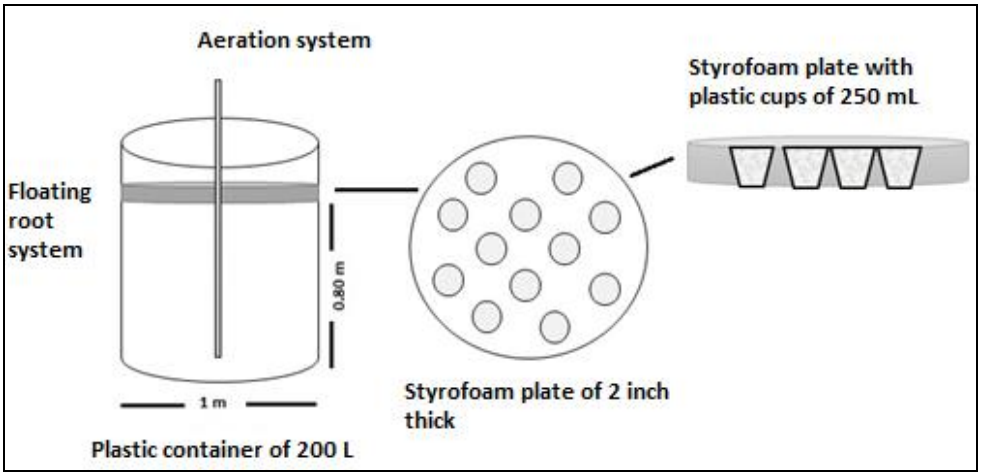

Fig 1: Aquaponics culture system

2.3 Organisms feeding

Fish were fed with an experimental diet made in the Live Food Production Laboratory. A food cube was supplied at 9:00 am and another at 3:00 pm, The daily portion was calculated from the 5% of total biomass of fish. Carbon source (Coffee, Yucca, Moringa, Macroalgae) was supplied once per day at 9:00 am, and was given in relation to 0.1% of total biomass.

2.4 Preparation of experimental diet

Diet consisted in the following ingredients: 250 g of spinach and carrot; 150 g of banana and apple, 100 g of red bell pepper; 500 g of broccoli; 300 g of beetroot; 200 g of chicken heart; 200 g of chicken gizzard; 360 g of Tuna meat (in water); 2 g of Vitamin E; and 28 g of hydrolyzed gelatin.

Process:

a) Gelatin (24 g) was hydrated in 1 L of cold water during 1 hr.
b) The carrot, banana and beetroot were pealed.
c) The spinach, carrot, red bell pepper, broccoli, and chicken heart and gizzard, were boiled for 15 minutes. At the end, the two pills of vitamin E were dissolved.
d) The tuna with the rest of the ingredients were liquefied to obtain a homogeneous mix.
e) Hydrated gelatin was placed during 20 seconds in the microwave to return to its liquid form and it was added to the mix (previously liquefied), in a plastic container.
f) To make the food cubes, plastic coolers with 16 holes were used, which were cleaned and sterilized with a swab with alcohol. The mix was allowed to cool for 1 hour, to later be covered with transparent adhesive paper and kept under refrigeration (5°C).

2.5 Organisms biometry

Every 15 days, 30 fishes were extracted to be weighed with the aim of a digital balance Nimbus ® with a precision of two decimals. Total length, height and width were measured with the aim of a Vernier. In plants it was only measured the total length (heigth).

2.6 Information processing

All biometric data of fish and plants were placed in an Excel data base 2010 to obtain the descriptive statistical. Also, the following measurements were obtained:
Weight and length gain with following formulas:
WG= Final weight – Initial Weight
LG= Final length – Initial length
Absolute growth rate (AGR) and intrinsic growth rate (IGR) with the following formulas:

$$AGR = \frac{\text{Final weight/length} - \text{Initial weight/length}}{\text{Time of experiment}}$$

$$IGR = \frac{(\text{Ln(Final weight/length)} - \text{Ln(Initial weight/length)})}{\text{Time of experiment}} x100$$

With mean values per sampling, it was obtained the growth tendency curves of considered biometric variables. One-way variance analysis (ANOVA) was made to determine significant differences ($P<0.05$), when they were found it was made a multiple mean analysis through a Tukey test, with aim of Statistical Program Systat 13.0.

3. Results

3.1 Survival

In the four experimental treatments, the organisms presented a survival of 90%. The treatment with Moringa had 100%, Yuca with 99%, Coffee with 98% and Macroalgae with 95%.

3.2 Fish total length

Mean values of total length of organisms during the 120 days of culture and its tendency curves are presented in Table 1 and Figure 2.

Table 1: Mean values (±S.D.) of the total length of fish cultured in the four experimental treatments.

Sampling day	Experimental treatments			
	Coffee	Yucca	Macroalgae	Moringa
0	2.78±0.51	3.21±0.40	3.26±0.45	2.66±0.36
15	3.79±0.48	3.37±0.51	3.50±0.50	3.26±0.49
30	4.07±0.48	3.49±0.47	3.64±0.52	3.50±0.38
45	4.09±0.49	3.76±0.38	3.81±0.38	3.65±0.37
60	4.35±0.37	4.34±0.36	4.20±0.36	3.98±0.38
75	5.32±0.45	5.43±0.43	4.96±0.42	4.75±0.46
90	7.50±0.47	7.19±0.39	6.24±0.52	6.24±0.39
105	11.36±0.48	9.81±0.40	8.22±0.52	8.70±0.52
120	14.39±0.45	13.47±0.36	11.06±0.42	12.42±0.52

Fish in Coffee treatment were the ones that reached a higher total length with 14.39±0.45 cm at the end of experimental period. The lowest value was found in macroalgae treatment with 11.06±0.42 cm. The other two treatments (Yucca and Moringa), had final lengths of 13.47±0.45 and 12.42±0.52 cm, respectively. The ANOVA showed significant differences ($p<0.001$) between all treatments. The highest gain of length was obtained with Coffee with 11.61 cm, as well as AGR (0.097 cm day^{-1}) and IGR (1.37% per day). The lowest value was in Macroalgae treatment with 7.80 cm of gain, an AGR of 0.065 cm day^{-1}, and a IGR of 1.01% of daily increase. Treatments with Yucca and Moringa had gain values of 10.26 cm and 9.76 cm, AGR of 0.097 and 0.081 cm day^{-1} and IGR of 1.37% and 1.28%, respectively.

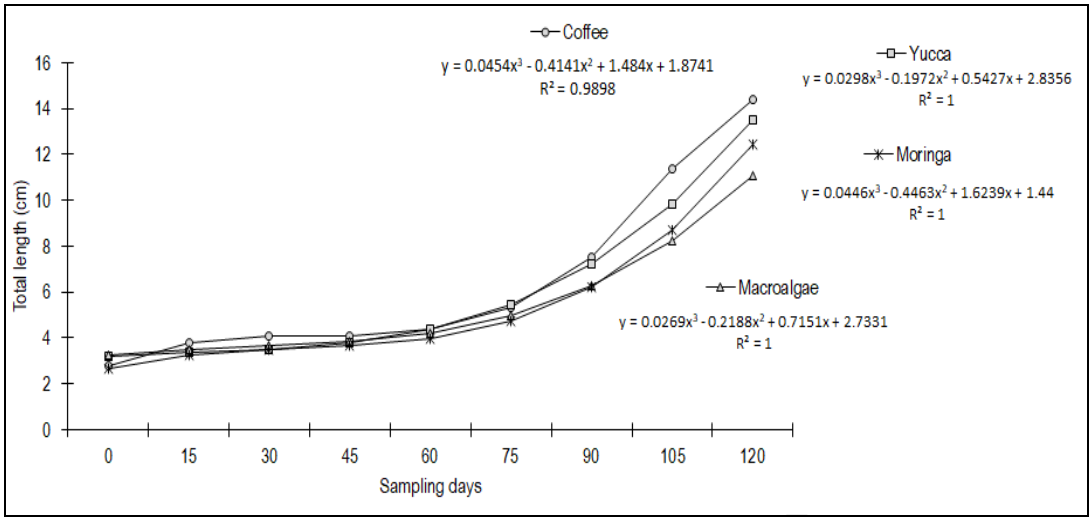

Fig 2: Growth tendency curve of total length of cultured fish in the four experimental treatments.

3.3 Fish width

Regarding to cultured fish width, the mean values per treatment are presented in Table 2 and Figure 3.

Table 2: Mean values (±S.D.) of width of cultured fish in the four experimental treatments

Sampling days	Experimental treatments			
	Coffee	Yucca	Macroalgae	Moringa
0	0.37±0.12	0.49±0.11	0.50±0.09	0.25±0.10
15	0.38±0.12	0.59±0.12	0.53±0.09	0.48±0.10
30	0.43±0.11	0.63±0.08	0.58±0.11	0.58±0.10
45	0.53±0.11	0.63±0.12	0.65±0.08	0.60±0.09
60	0.67±0.09	0.64±0.09	0.73±0.12	0.63±0.11
75	0.85±0.08	0.69±0.08	0.83±0.10	0.75±0.12
90	1.07±0.10	0.83±0.11	0.95±0.08	1.03±0.08
105	1.34±0.10	1.09±0.08	1.09±0.10	1.56±0.08
120	1.65±0.10	1.51±0.10	1.25±0.08	2.41±0.09

Fish in moringa treatment are the ones that presented the highest width mean values with 2.41±0.09 cm, while the lowest value was in macroalgae fish with 1.25±0.08 cm. The treatments with Coffee and Yucca showed values of 1.65±0.10 cm and 1.51±0.10 cm respectively, in the 120 days of culture. The ANOVA showed significant differences ($p<0.05$) between all treatments. The highest gain of width was presented in fish with moringa treatment with 2.16 cm, with an AGR of 0.018 cm day^{-1} and an IGR of 1.90%. The lowest value was obtained in Macroalgae treatment with only 0.75 cm of gain, an AGR OF 0.006 cm day^{-1} and an IGR of 0.76%. Treatments with yucca and coffee obtained gain values of 1.02 and 1.28 cm, AGR of 0.008 and 0.011 cm day^{-1} and IGR of 0.93% and 1.24%, respectively.

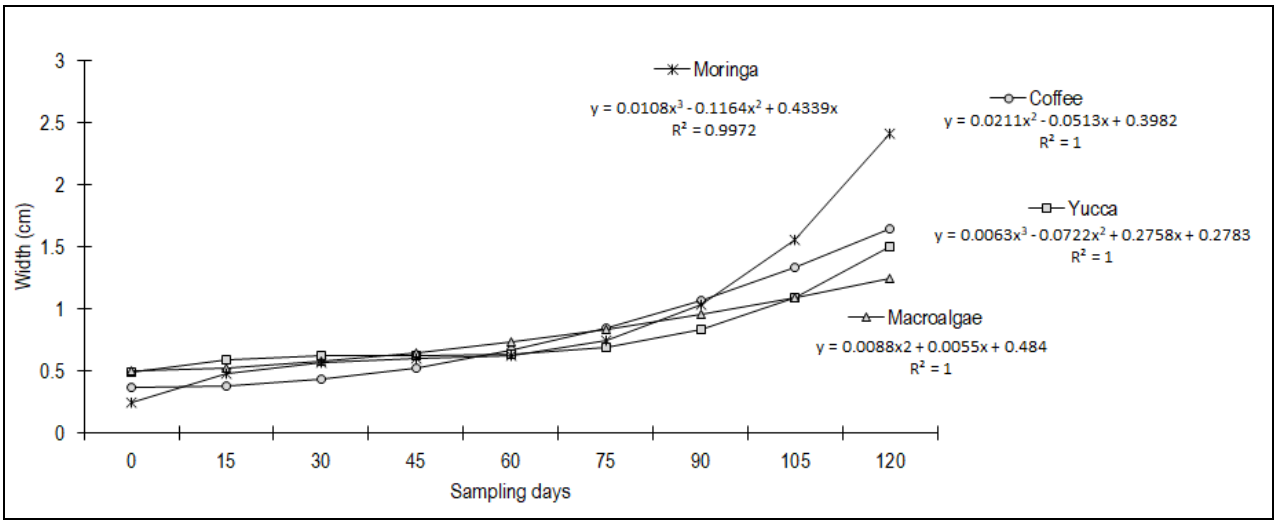

Fig 3: Growth tendency curve of fish width cultured in the four experimental treatments

3.4 Fish weight

Mean values of cultured fish weight are presented in Table 3 and Figure 4.

Table 3: Mean values (±S.D.) of cultured fish weight in the four experimental treatments

Sampling days	Experimental treatments			
	Coffee	Yucca	Macroalgae	Moringa
0	0.82±0.30	0.88±0.33	0.95±0.34	0.81±0.35
15	0.95±0.31	0.96±0.28	1.00±0.37	0.99±0.38
30	1.91±0.32	1.93±0.28	2.01±0.32	1.99±0.38
45	2.86±0.41	2.89±0.31	3.01±0.34	2.98±0.39
60	3.82±0.42	3.86±0.31	4.01±0.35	3.97±0.35
75	4.77±0.35	4.82±0.35	5.01±0.38	4.96±0.39
90	5.72±0.42	5.78±0.42	6.02±0.36	5.96±0.29
105	6.68±0.38	6.75±0.42	7.02±0.29	6.95±0.37
120	7.63±0.29	7.71±0.36	8.02±0.28	7.94±0.37

The fish that presented higher weight mean values were the ones in macroalgae treatment (8.021±0.28 g), while the lowest value was found in the coffee treatment (7.63±0.29 g). The treatments with yucca and moringa presented values of 7.71±0.36 g and 7.49±0.37 g, respectively. ANOVA analysis did not show significant differences between treatments. Highest weight gain was presented in the moringa treatment with 7.13 g, as well as AGR (0.059 g day^{-1}) and IGR (1.90% per day). Lowest value was presented in coffee treatment with 6.81 g of gain and a AGR of 0.057 g day^{-1}, and a IGR of 1.85% per day. Treatments with yucca and macroalgae had gain values of 6.83 and 7.13 g, AGR of 0.057 and 0.059 g day^{-1} and an IGR of 1.80% and 1.90% of increase per day, respectively.

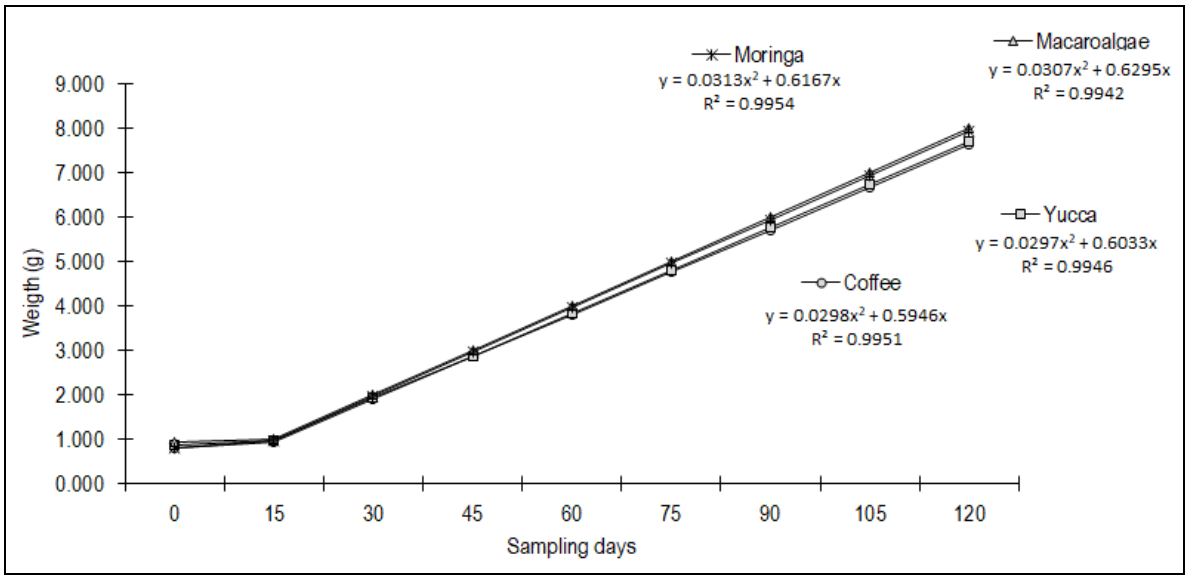

Fig 4: Growth tendency curve of weigh in cultured fish in the four experimental diets.

3.5 Well-being factor (WF)

In the four experimental treatments, the organisms remained at the initial K. Only the treatment with coffee, by day 15 of experiment, presented lower values. For day 45 and 75 of experiment it was observed a higher increase in weight as well as in total length of fish (Fig.5).

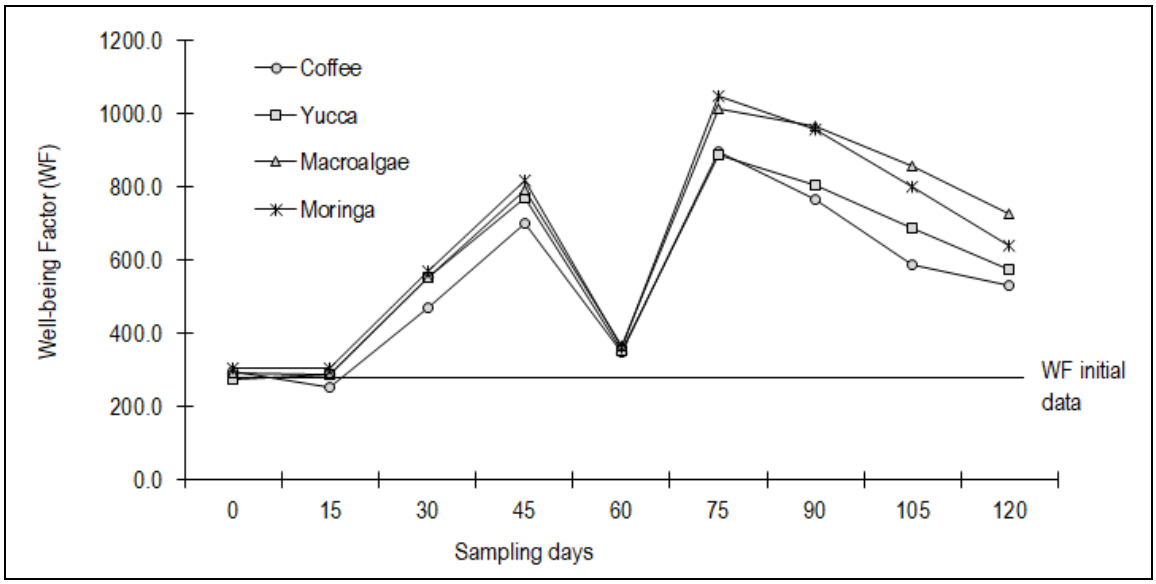

Fig 5: Degree of well-being or condition factor (K) of cultured fish in the four experimental treatments.

3.6 Total length of cherry tomato

In Table 4 and Figure 6 are presented the mean values of total length of cherry tomato plants, as well as its growth curve.

Table 4: Mean values (±S.D.) of the total length of tomato cherry plants placed in a floating root system over experimental treatments of fish culture.

Sampling days	Experimental treatments			
	Coffee	Yucca	Macroalgae	Moringa
0	11.00±1.36	10.37±2.09	14.40±1.60	12.10±1.59
15	13.17±0.98	13.08±0.85	14.92±2.06	13.33±0.98
30	13.50±0.88	14.00±1.91	15.00±1.53	13.80±1.71
45	13.58±1.29	14.08±1.14	15.08±1.56	14.17±2.00
60	15.00±1.59	14.30±1.01	15.60±1.59	15.10±2.06
75	19.34±1.60	15.62±1.56	16.98±1.40	17.26±1.51
90	28.17±1.90	19.00±1.62	19.66±1.70	21.33±0.87
105	43.09±0.98	25.41±1.68	24.08±1.82	27.96±1.52
120	65.67±1.46	35.83±0.82	30.66±1.62	37.83±1.42

The tomato cherry plants that presented higher total length mean values were the ones in coffee treatment (65.67±1.46 cm), while lowest value was for macroalgae treatment (30.66±1.62 cm). Yucca and moringa treatments presented values of 35.83±0.82 cm and 37.83±1.42 cm, respectively. ANOVA analysis showed significant differences between treatments (p<0.001). Highest length gain was with coffee treatment with 54.67 cm, AGR of 0.45 cm day^{-1} and IGR of 1.49% of daily increase. Lowest value was presented in macroalgae treatment with 16.26 cm, an AGR of 0.13 cm day^{-1}, and an IGR of 0.63% of daily increase. Yucca and moringa treatments presented gain values of 25.46 and 25.73 cm, an AGR of 0.21 cm day^{-1} in both treatments and an IGR of 1.03% and 0.95% of daily increase, respectively.

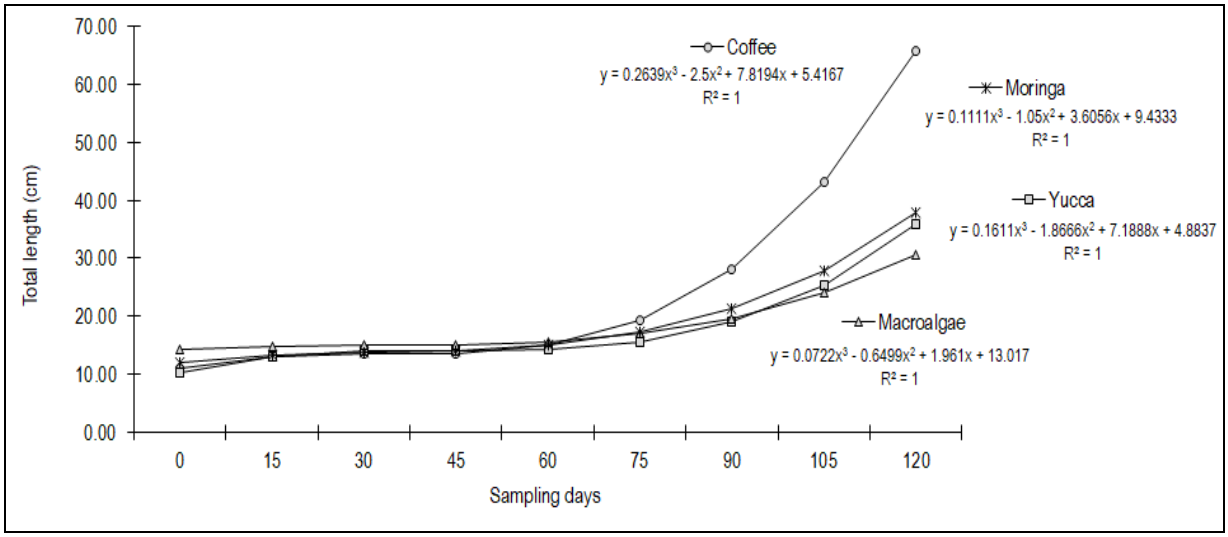

Fig 6: Growth tendency curves of tomato cherry plants total length in the four experimental treatments

4. Discussion

Nowadays, most studies regarding BFT are focused in shrimp culture and very few in fish [14]. Also, there are not many studies about the effect of other carbon sources, different to molasses, in growth, water quality and Biofloc composition, important characteristics for fish culture. Obtained results of survival higher of 90% in the four experimental carbon sources, allow to present the viability of culture of ornamental fish in Biofloc system.

Cyprinus carpio in Biofloc with different carbon sources [9], obtaining the highest weight gain in organisms with moringa as carbon source, like what was obtained in this study where organisms with moringa obtained the highest mean value of weight gain with 7.13 g.

Regarding to growth efficiency [15], these authors cultured *Melanochromis auratus* during 16 weeks in a water recirculation system, they obtained a mean weight gain of 9.37 g by feeding them with trout pellet (50% of protein) and 6.03 g when feeding them with tropical granule (42% of protein). The obtained weight gain with trout pellet is higher than the ones in this experiment, because the highest obtained gain was of 7.13 in moringa treatment. On the other hand, the weight gain they obtained with tropical granule was lower than the ones obtained in this experiment, where the lowest gain was 6.81 g in the coffee treatment. Meanwhile, obtained length gain in this work in all treatments was higher than the ones obtained in Karadal *et al*. (2018), because the highest length gain they obtained was 5.04 cm with the organisms fed with trout pellet, while the lowest length gain in this work was of 7.80 cm in the macroalgae treatment.

Regarding to cherry tomato growth experiment [16], in a tilapia culture, these authors reported a growth up to 60 cm in the tomato plant, using compost and water from fish culture, similar values were obtained in this experiment, because the plant reached 65.67 cm using coffee residuals as carbon source for Biofloc production in cichlid culture. Another authors [17], which used beds without circulation (open) and with circulation (closed) treatments with a nutritive solution to produce tomato, reaching a plant height of 64.0 cm in a short period of 25 days; they reached a plant height of 89 cm in 92 days. Unlike our experiment, the slow growth of the plant could be due to the lack of incorporation of a nutritive solution necessary for a good growth of tomato plant [18, 19].

6. Conclusion

Biofloc/Aquaponic system at small scale viability to cultured *Melanochromis* sp. can be confirm with the obtained results. Regarding to *Lycopersicon esculentum* culture, this system allows only the stem and leaf's growth. It is necessary to use a better nutritional solution to produce flowers and fruits.

Biofloc culture system allow to use wastewater, because bacterial present in the flocs can transform the toxic nitrogen compounds in fish culture. The produced flocs can be use as fish food. Biofloc can be used as complement fertilizer to plants.

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